Established by BENJAMIN SILLIMAN in 1818.

LIBRARY OF THE UNIVERSITY OF DETROIT

THE

AMERICAN JOURNAL OF SCIENCE.

EDITOR: EDWARD S. DANA.

ASSOCIATE EDITORS

PROFESSORS GEORGE L. GOODALE, JOHN TROWBRIDGE, W. G. FARLOW AND WM. M. DAVIS, OF CAMBRIDGE,

PROFESSORS ADDISON E. VERRILL, HORACE L. WELLS, L. V. PIRSSON AND H. E. GREGORY, OF NEW HAVEN,

PROFESSOR GEORGE F. BARKER, OF PHILADELPHIA,
PROFESSOR HENRY S. WILLIAMS, OF ITHACA,
PROFESSOR JOSEPH S. AMES, OF BALTIMORE,
MR. J. S. DILLER, OF WASHINGTON.

FOURTH SERIES.

VOL. XVIII—[WHOLE NUMBER, CLXVIII.]

No. 107.—NOVEMBER, 1904.

WITH PLATES XVII–XIX.

NEW HAVEN, CONNECTICUT.

1904

THE TUTTLE, MOREHOUSE & TAYLOR CO., PRINTERS, 123 TEMPLE STREET.

Published monthly. Six dollars per year, in advance. $6.40 to countries in the Postal Union. Remittances should be made either by money orders, registered letters, or bank checks (preferably on New York banks).

JUST OUT

"COMPLETE MINERAL CATALOG."

The most up-to-date compilation of the kind in print.

"*The Metallic Classification*" under each metal heading shows every mineral carrying such metal. Sub-divisions give the combination in which the metal occurs.

"*Dana's Classification*" is the most generally accepted mineralogical system. In this synopsis of Dana's great work is found name, composition and crystalline form of each species, as well as its varieties and related compounds.

"*The Alphabetical Index*" indicates by number the position of each mineral in this classification. Specimen prices are also shown.

"*Choice Minerals*" from many countries are briefly described and illustrated by numerous handsome engravings.

Systematic Collections of minerals are fully described and detailed lists given. Contains 216 pages of useful data for all interested in pure or applied mineralogy.

Prices, postpaid, to any address: Paper, $0.25; bound in flexible cloth, $0.50.

FOOTE MINERAL CO.,

Established 1876.

DEALERS IN

Minerals for Educational and Industrial Purposes.

☞ NOTE CHANGE IN EUROPEAN ADDRESS.

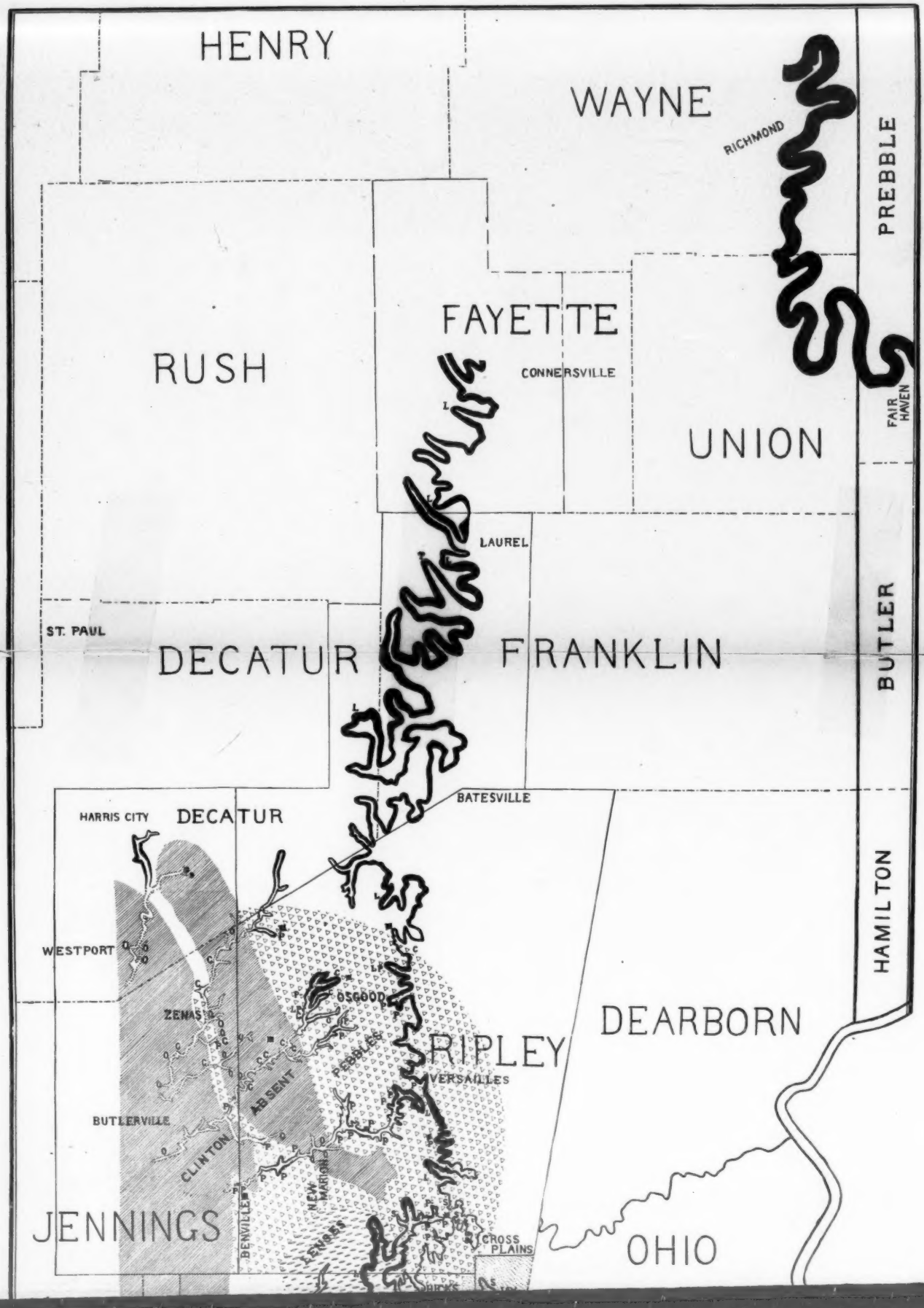
1317 Arch Street,
PHILADELPHIA.
Two minutes walk from City Hall

52 Rue St. Georges,
PARIS.
Five minutes walk from the Opera.

Map of Southeastern Indiana, showing thickness of Clinton and outlines of Ripley Island area.

DECATUR
FRANKLIN
BU
HARRIS CITY
DECATUR
BATESVILLE
HAMILTON
WESTPORT
OSGOOD
ZENAS
DEARBORN
RIPLEY
PEBBLE
VERSAILLES
ABSENT
BUTLERVILLE
CLINTON
NEW MARION
JENNINGS
BENVILLE
LENOX
CROSS PLAINS
OHIO
RICHE
JAY

Am. Jour. Sci., Vol. XVIII, 1904.



THE

AMERICAN JOURNAL OF SCIENCE

[FOURTH SERIES.]

ART. XXXVI. — *The Ordovician-Silurian Contact in the Ripley Island Area of Southern Indiana, with notes on the age of the Cincinnati geanticline;* by AUG. F. FOERSTE. (With Plate XVII.)

Cincinnati Geanticline.

THE axis of the Cincinnati geanticline, a low fold, extends from the northern part of Alabama through central Tennessee and Kentucky into southwestern Ohio and the adjacent part of Indiana. Northward it branches, one axis reaching the western end of Lake Erie,* the other extending northwestward across the northern half of Indiana† into northern Illinois. In Tennessee the rocks dip southeastward as far as Walden Ridge and Cumberland Mountain, a distance varying from 75 to 100 miles; on the western side of the axis the dip is westward or northwestward at least as far as the Tennessee river, a distance of 100 miles; farther west, the Tertiary deposits conceal the Paleozoic rocks involved in the fold. In the southern half of Kentucky the rocks dip westward for a distance of at least 100 miles. From the northern half of Kentucky the dip is westward across the state of Indiana as far as the eastern part of Illinois, a distance approximately of 200 miles. Northward, the rocks dip westward from the western branch of the axis across Indiana and the eastern third of Illinois. Eastward, the rocks dip from the eastern branch of the axis across the state of Ohio as far as western Pennsylvania and the western part of West Virginia, the maximum distance being at least 180 miles.

Over the greater part of the area the dips are too low to be detected from any single point of view. As a rule, however, a comparison of levels of corresponding strata from exposures

* Ohio. Geol. Surv., vi, 1888, map opposite p. 48.
† Indiana Geol. Surv., 18th Rept., 1894, p. 221.

several miles apart gives unmistakeable evidence of dip. Locally the dips may be conspicuous though rarely exceeding 30 degrees; however, the local nature of these dips is detected easily, and usually is connected with folds and domes of rather small extent. These local folds and domes are much more numerous in the southern half of Kentucky and in Tennessee than in the northern half of the area affected by the geanticline, although tilted rocks are not uncommon along the western branch of the axis in northern Indiana.

The rocks involved in the folding include all of the Paleozoic formations. Ordovician strata are exposed along the greater part of the axis between northern Alabama and a point 26 miles north of Dayton, Ohio, a total distance of 400 miles. In the southern half of Kentucky there is a sag along the axis in consequence of which the crest of the geanticline is formed by Mississippian (sub-Carboniferous) strata. North and south of this sag of the axis, along the crest of the geanticline, are two areas of considerable extent in which the Ordovician exposures are practically continuous. Of these the southern area,* 75 miles long and nearly 50 miles broad, includes all of central Tennessee. The northern area,† 150 miles long and 85 miles broad, includes the northern part of Kentucky and the adjacent parts of Ohio and Indiana, between the towns of Lebanon, Richmond, and Maysville, Kentucky, Dayton, Ohio, Richmond, and Madison, Indiana. That part of the Cincinnati geanticline including the southern Ordovician area is occasionally referred to as the Nashville dome, while the part including the northern Ordovician area is sometimes called the Kentucky uplift or Cincinnati dome. Farther northward in Ohio‡ and Indiana§ the crest of the eastern and western branches of the Cincinnati geanticline is formed by Silurian strata.

Silurian Strata of Geanticline.

No trace of the Lower or Oswegan division of the Silurian, including the Oneida and Medina, is exposed anywhere in the area affected by the Cincinnati geanticline. Middle Silurian or Niagaran exposures, however, ranging from the Clinton to the Guelph, are abundant. Cayugan or Upper Silurian exposures, including rocks formerly known as Waterlime,‖ are known to occur in several areas but have not been studied. In

* Geology of Tennessee, by James M. Safford, 1869, map.

† The Richmond group along the western side of the Cincinnati anticline in Indiana and Kentucky, Am. Geol., 1903, pl. 20; Silurian outcrops indicated by dotted line.

‡ Ohio Geol. Surv., vii, 1893, map.

§ Indiana Geol. Surv., 19th Rept., 1894, map; much more accurate map now in press.

‖ Silurian and Devonian limestones of western Tennessee, Journ. Geol., xi, 1903, pp. 701, 702.

Ohio, Cayugan formations extend from the western Put in Bay islands in the western part of Lake Erie into Lewis county in northern Kentucky, crossing the Ohio river at Vanceburg, Ky. In Indiana, Cayugan strata are known only from Kokomo, although their occurrence in northeastern Indiana has been considered probable.

In Indiana, the Niagaran has been divided into the following subdivisions, named in descending order: Louisville, limestone; Waldron, clay; Laurel, limestone; Osgood, clay and limestone; Clinton, limestone.

Pre-Meso-Devonic origin of the Cincinnati Geanticline.

Along the western flank of the geanticline, in Kentucky and Tennessee, the edges of these subdivisions of the Niagaran, where not covered by overlying subdivisions of the same Niagaran series, thin out eastward toward the Ordovician axis,* and are overlaid unconformably by Middle Devonian limestones or by Devonian black shale. Along the eastern flank of the geanticline, in Kentucky, the uncovered edges of Silurian formations equivalent to the Clinton and Osgood beds thin out in a similar manner westward toward the same Ordovician axis and are also overlaid uncomformably by Middle Devonian limestones or by Devonian black shale. No Silurian rocks are exposed along the eastern margin of the Ordovician area in Tennessee. However, their presence in the Sequatchie valley indicates that Silurian strata exist also along the eastern flank of the geanticline in Tennessee, but are concealed by the cover formed by later strata. The character of the unconformity between the Niagaran and Devonian formations places the origin of the Cincinnati geanticline in times preceding the Middle Devonian.

Pre-Niagaran origin of Geanticline.

Inconclusive nature of certain arguments advanced.—In western Tennessee, Professor Safford and others thought they could trace the upper Niagaran formations up the western flank of the geanticline, farther eastward than the lower Niagaran formations, the former overlapping the latter. From this they concluded that the origin of the Cincinnati geanticline took place in times preceding the deposition of the Niagaran. More recent investigations have not confirmed this overlapping of the upper Niagaran formations, so that this argument becomes ineffective. Other writers have regarded the thinning of the Silurian formations from the flanks toward the crest of the geanticline as sufficient evidence of pre-Niagaran origin.

* Silurian and Devonian limestones of Tennessee and Kentucky, Bull. Geol. Soc. Am., xii, pp. 398, 422. The Cincinnati anticline in southern Kentucky, Am. Geol. 1902, pl. 26; Am. Geol., 1903, pl. 20.

This argument also has lost force since it has been discovered that along the western flank of the geanticline the conspicuous thinning of Niagaran formations toward the east is confined to the edges* of the Niagaran formations, where in succession they project from beneath the immediately overlying Niagaran beds on approaching the crest of the geanticline; and where the thinning of the strata might have been caused by erosion subsequent to their deposition. The same strata fail to show any conspicuous thinning eastward where the immediately following subdivision of the Niagaran is present. Under these conditions it is not possible, without further evidence, to exclude the alternative proposition, that the Niagaran, at least the Clinton and the equivalents of the Osgood clay, originally may have extended across the region of the present Cincinnati geanticline, gradually thinning out westward; that during late Silurian or early Devonian times a geanticlinal uplift occurred, accompanied by removal of Silurian strata along the crest of this uplift and resulting in a conspicuous thinning of the edges of the various Niagaran strata toward the crest of the geanticline wherever exposed by the removal of overlying Niagaran formations. This alternative proposition would demand the operation of geological processes resulting in baselevelling, the Devonian formations being deposited upon the baselevelled edges of the Niagaran. It should be remembered however that, at present, evidence favoring baselevelling of Niagaran strata is confined to the conspicuous thinning of the edges of Niagaran formations toward the crest of the geanticline where not protected by the next overlying Niagaran formations, and the absence of a similar conspicuous thinning in the same direction where the next overlying Niagaran formation is present. It seems scarcely possible that baselevelling could have taken place over areas as large as those exposed along the crest of the Cincinnati geanticline without leaving other evidence than that offered by the thinning of strata as just described.

During the earlier operations of the Geological Survey of Ohio under Professor Orton, thin layers of conglomerate were discovered in the Clinton at Belfast† in Highland county, 57 miles east of Cincinnati, Ohio. The fossils in the pebbles of this conglomerate were believed to have been of Ordovician age, but subsequent investigations proved their Clinton origin, and that older strata of Clinton age had been broken up during the formation of this conglomerate. The presence of conglomerate was believed to be conclusive evidence of the pre-Niagaran origin of the Cincinnati geanticline. It is scarcely neces-

* Silurian and Devonian limestones of Tennessee and Kentucky, Bull. Geol. Soc. Am., 1901, pp. 408–414, fig. 5.

† Ohio Geol. Rept., Surv. for 1870, p. 270. On Clinton conglomerates and wave marks in Ohio and Kentucky, Journ. Geology, iii, 1895, pp. 1-4, 23–26.

sary to point out the inconclusiveness of this evidence founded on observations at a single locality; however in view of opinions as to the age of the Cincinnati geanticline then generally current, the predication of the pre-Niagaran origin of the geanticline on the basis of this Belfast exposure of conglomerate is certainly comprehensible. Moreover, it is not impossible that at some future time, in combination with other evidence not yet at hand, it may prove to have an important bearing upon the subject.

More recent observations upon the Clinton of Indiana have brought to light facts which are of interest in this connection.

Ordovician-Silurian Contact in Ripley Island Area of Southeastern Indiana.

Base of Silurian.—When the investigation of Silurian strata in Indiana was begun, the pre-Silurian origin of the Cincinnati geanticline was accepted. In Ohio the Clinton was known to become thinner westward. Near the Ohio river, in Adams and Highland* counties, exposures equalling 35 feet, in some instances possibly 40 feet, are seen. Northwestward, in Clinton county, the Clinton has a thickness of at least 25, possibly 30 feet. Still farther northwest, east of the Miami river, in the northeastern part of Montgomery and the southeastern part of Miami county, the thickness varies between 23 and 28 feet. Passing from the northern half of this northwesterly running line of outcrop toward the southwest, the rate of diminution of the Clinton is much more rapid. At Sunderland Falls and at Ludlow Falls the thickness is about 22 feet. At Fauvers quarry, 2 miles north of Dayton, west of the Stillwater river, and at Centreville, 9 miles south of Dayton, the thickness is 17 feet. At the Betty Heidy exposure, about a mile east of Oregonia, the thickness is at least 14 feet, and possibly equalled 16 feet. At the Soldiers' Home, west of Dayton, it is about 15 feet. At Lewisburg and Eaton, the thickness is 13 feet. East and southeast of Richmond in Indiana it is about 11 feet. About 12 miles southwest of Eaton, six miles east of the state line, the thickness does not appear to exceed nine feet.

The decrease in thickness of the Clinton toward the southwest continues in Indiana.† Glacial deposits cover the Clinton in the western part of Wayne county, but in the western part of Fayette and Franklin counties the thickness of the Clinton usually does not exceed 6, but occasionally attains 8 feet, and frequently is reduced to 4 feet or even less. Southward, across the center of Ripley county, the thickness of the Clinton con-

* An account of Middle Silurian rocks of Ohio and Indiana, Journ. Cincinnati Soc. Nat. Hist., xviii, 1896.

† Indiana Geol. Surv., 21st Rept. p. 213; and 22nd Rept. p. 195.

tinues to diminish, but southwestward, in the western part of Ripley and the adjacent parts of Jennings and Decatur counties, the Clinton is entirely absent. These facts were entirely unexpected. In keeping with preconceived views of the early, pre-Silurian origin of the Cincinnati geanticline, it was believed that after crossing the axis of the geanticline the thickness of the Clinton would increase instead of decrease westward. Instead, a fairly regular decrease in thickness across the axis of the geanticline was noted, beginning with the most northeastern exposures in Ohio, and continuing to the most southwestern of the series of exposures so far discussed.

The area, or areas, from which the Clinton is absent is here called the Ripley island or islands. The outlines of this area are known only along the eastern border, and even here much remains to be determined. The facts so far discovered are indicated on the accompanying map (Plate XVII). East and southeast of the Ripley island area the Clinton contains pebbles.

These pebbles which occur in the Clinton are usually confined to the lower 4 to 6 inches of the formation. They are commonly not more than an inch in length, although pebbles 2 and even 3 inches in length are recorded from several localities, and at one locality thin flat pieces of rock, 6 to 8 inches in length, were included. Most of these pebbles consist of a very fine-grained white limestone, belonging to the very top of the Ordovician of this part of Indiana. The most common fossil in this white rock is *Tetradium minus*, but this rarely appears in the pebbles. Not infrequently the white limestone occurs directly beneath the Clinton; occasionally in such situations it is cracked and the cracks are filled with the salmon-brown detrital material of which the Clinton is formed in this part of Indiana; the contrast in color is striking. Occasionally the white limestone is cracked also where it occurs at some distance beneath the Clinton and the cracks are filled with clay. Sometimes worm-borings penetrate for several inches into the top of the white limestone, and the cavities are filled with the salmon-brown Clinton material. The pebbles formed from this limestone are frequently very angular in shape, sometimes having the appearance of derivation from some brecciated rock, at other times with the corners conspicuously rounded. It appears that before the deposition of the Clinton, this white limestone was a soft calcareous mud into which worms could bore; owing to shrinkage it cracked into rather small irregular fragments; this shrinkage may have been caused by drying owing to exposure of the surface to the sun; the surface of the Clintonless area may have been in the condition of flats within the reach of high tides; the fragments produced by cracking were often washed toward regions of deposition; those longest exposed to the air

and most hardened, and those transported the shortest distance, were left most angular. Occasionally fragments of Ordovician limestone, formed by the detrital remains of shells and bryozoans comminuted so as scarcely to be recognizable, have been caught up by the Clinton. In these cases the fragments of limestone consist usually of thin slabs. It appears that this limestone of detrital origin solidified more rapidly than the very fine-grained mud forming the white limestone, probably because the detrital limestone permitted a freer circulation of water. In these detrital limestone pebbles *Rafinesquina alternata* and other Ordovician fossils are found. The localities from which pebbles in the Clinton have been recorded are indicated on the map by the letter P; they undoubtedly include only a small part of the localities at which pebbles occur.

South of Laurel, those exposures of the Clinton which indicate a detrital origin usually have a salmon-brown color. The detrital material usually is fairly coarse. The absence of the finer material which must have resulted from the attrition is probable due to currents which were strong enough to sweep along the finer material but left the coarser particles behind to form the Clinton deposit. Sometimes this fine-grained material appears to have been allowed to deposit for a short time, producing thin layers, but as a rule these layers were swept away again later; however their former existence is suggested by the presence in the salmon-brown Clinton of thin lenses of fine-grained whitish limestone, usually widely separated but sometimes connected by very attenuated sheets of the same material. Some of the localities at which these white lenses occur in the salmon-brown Clinton are indicated on the map by the letter L. The lack of distinct bedding or the presence of cross bedding is another evidence of the deposition of the Clinton under the influence of rather strong, irregular currents.

Where the Clinton is absent in Indiana, the lowest layers of the Osgood rest directly upon the Madison bed. At one locality 4 miles west-southwest from Osgood, a single pebble of salmon-brown Clinton rock with blotches of black was found enclosed in the white limestone forming the base of the Osgood beds, 2 inches above the Ordovician. The pebble was 3 inches long, almost 3 inches wide, and half an inch thick. This is the only pebble found at any point in the Osgood bed. Immediately beneath was clay with *Tetradium*, and farther down occurred limestone including concretionary masses or some species of *Strephochetus*.

The presence of areas from which the Clinton is absent, surrounded by areas in which the Clinton contains pebbles of Ordovician origin, is an indication of course of unconformity

between the Silurian and Ordovician in this area. In seeking to determine the measure of the erosion of Ordovician rocks in times preceding the deposition of the Silurian in the Clinton-less areas, it was expected that the Silurian would be found to rest upon Ordovician rocks of a considerably lower horizon where the Osgood rested directly on the Ordovician, than at more remote points where the Clinton was present and the pebbles were absent. No striking difference was noted. The detailed observations are presented on the following pages.

Top of Ordovician.—In Indiana, Ohio, and Kentucky, the Cincinnati group at the top of the Ordovician is divided into the Utica, Lorraine and Richmond, named in ascending order. The Richmond is further subdivided into the Waynesville, Liberty, Whitewater, and Madison beds, also named in ascending order. The Madison bed has also been called the Saluda bed, since the name Madison was employed earlier elsewhere. The thickest exposures of the Madison bed are found on the western side of the Cincinnati geanticline, along the Ohio river and thence northward to Laurel, Indiana.

In the neighborhood of Madison,* Indiana, a layer of massive corals, often of large size, has been adopted as marking the base of the Madison bed. These corals are *Columnaria alveolata*, *Columnaria halli*, and occasional specimens of *Calopoecia cribriformis*. *Tetradium minus* occurs 6 feet and, again, 7·5 feet above the massive coral layer, sometimes also 2 feet below the same. Associated with the *Tetradium*, about 6 feet above the massive coral layer, are found *Cyrtolites ornatus*, *Bellerophon capax*, *Lophospira bowdeni*, *Hormotoma gracilis*, *Ischyrodonta miseneri*, *Pterinea demissa*, and a small form of *Platystrophia* with a short hinge line. In the sandy layer immediately above are found *Rhynchotrema capax*, *Strophomena sulcata*, *Strophomena vetusta*, *Dinorthis subquadrata*, *Hebertella sinuata*, *Streptelasma rusticum*, *Streptelasma divaricans*, *Beatricea undulatum*, and a large irregular lobate species of *Heterospongia*. As a rule fossils are scarce at this horizon elsewhere in southern Indiana, with the exception of *Tetradium*, which is quite constant, and often very abundant, at this level.

The lower part of the Madison bed at Madison, 15 feet thick, consists chiefly of clayey rock weathering readily. The greater part of the remainder of the Madison bed, forming a section 32 feet thick, consists of a massive appearing more or less sandy limestone, nearly unfossiliferous, often forming abrupt vertical walls over which plunge the small streams leading to the Ohio. This more massive rock oftens shows color-banding and is the

* Indiana Geol. Surv., 21st Rept. 1897, pp. 248, 249; the lists of fossils by Dr. Cornett and Prof. Cox are in error.

banded rock of earlier surveys, formerly believed to correspond to the Medina of New York.

At the top of the Madison section is a peculiar bluish limestone weathering in a very irregular manner, and containing a considerable fauna which has been only partially studied. Among other fossils may be mentioned *Cyrtocerina madisonense*, *Orthoceras* several species, *Ischyrodonta truncata*, *Ischyrodonta* cf. *miseneri*, *Ctenodonta simulatrix*, *Rhytima* sp. near *oehana* in size, *Byssonychia* several species, *Lophospira hammelli*, *Liospira*, *Holopea hubbardi*, *Labechia ohioensis*, and various species of ostracoda.

On tracing the Madison bed northward from Madison the massive coral bed at the base does not prove to be a conspicuous feature for any great distance, nevertheless in an inconspicuous form it proves constant to its proper horizon as far north as Osgood at least. Here along the stream following the old line of the Baltimore and Ohio Southwestern railroad, about two miles northeast of the town, specimens of *Columnaria alveolata* are rather common immediately below the beds containing *Tetradium; Hebertella insculpta*, marking the base of the Liberty bed, occurs just below the junction of this stream with Laughery creek, with the normal vertical interval. At Versailles, however, specimens of *Columnaria alveolata* are rather rare, though some of large size are found occasionally at the proper horizon.

The *Tetradium* bed, on the contrary, often gains in importance northward. At Versailles its thickness is eight and a half feet, *Columnaria alveolata* occurring 16 inches lower down. At Osgood, it rests immediately upon the *Columnaria alveolata* bed. At the Derbyshire Falls, southwest of Laurel, the *Tetradium* bed has a vertical thickness of three and a half feet; *Hebertella insculpta*, marking the base of the Liberty bed, occurs at the proper vertical interval along the road leading from Laurel to Metamora, a short distance south of the crossing over the stream which flows from the Falls to the river.

At Madison, and southward along the Ohio river, the most characteristic part of the Madison bed is the massive sandy brownish rock, 32 feet thick, forming the upper two-thirds of the section. This phase continues northeastward from Madison across the eastern half of Jefferson county. Northwest of this line, however, toward Versailles, New Marion, Butlerville, and northward, there is a considerable change in the lithological appearance of this part of the Madison bed section. The first change is seen 5 miles north of Madison, at the crossing of Razor creek over the Graham road; here the upper part of the section equivalent to the massive brownish sandy bed is more whitish, more calcareous, and less sandy. Two miles farther

north the upper part of the Madison bed, 14 feet thick, is again massive brownish and sandy; the middle and lower part, 40 feet thick, is soft and weathers readily; *Columnaria alveolata* occurs at the base, and *Tetradium* is found 8 feet higher up. A mile and a half farther north, at Belleview, that part of the section equivalent to the upper part of the massive bed, 20 feet thick, is again more calcareous, of a more whitish or bluish color, sometimes slightly tinged with purple; it has a much more calcareous appearance, often weathers very irregularly, and evidently corresponds closely in appearance to the greater part of the Madison bed as exposed at Versailles, New Marion, Butlerville, Nebraska, and northward as far as Osgood and Zenas. This whitish or bluish calcareous form of the Madison bed is the phase most characteristic of the area in which the Clinton is absent, and in the areas immediately adjacent. In this whitish or bluish, more calcareous phase of the Madison bed, fossils, especially bryozoans, are less rare, and at some horizons, especially near the top, are even common locally. That part of the Madison section at Belleview which corresponds to the lower part of the massive division of the section at Madison, retains its brownish, more massive appearance and its practically unfossiliferous character. This part of the section, 15 feet thick, may be traced northward to Versailles, where it forms the unfossiliferous brownish shales, 9 feet thick, immediately overlying the *Tetradium* bed. These unfossiliferous shales occupy the same position along the stream following the old right of way formerly used by the Baltimore and Ohio Southwestern railroad 2 miles northeast of Osgood.

The fauna occurring at the top of the Madison bed at Madison, Indiana, including *Lophospira hammelli*, *Holopea hubbardi*, and other fossils, may be traced northward 2 miles beyond the line between Jefferson and Ripley counties. This fauna is not confined to the top of the Madison bed, but may occur at several levels, although always in the upper part of the Madison bed. Occasionally it occurs in the upper part of the layers which are equivalent to the more massive part of the Madison section, sometimes even 7 feet below their usual horizon. Farther northward, in Ripley county, in the adjacent part of Jennings county, and in the greater part of the area from which the Clinton is absent and within which pebbles are found in the Clinton, the equivalents of the *Lophospira hammelli* and *Holopea hubbardi* beds consists of sandy clays and clayey limestones containing numerous branching bryozoans and also a fair brachiopod fauna. These beds are described in the following paragraphs.

A mile and a half south of Versailles, south of the home of William Rosengarn, the sandy clay at the top of the Madison

bed, 10 feet thick, contains *Byssonychia obesa*, *Ctenodonta cingulata*, a form of *Hebertella occidentalis* in which the median depression of the brachial valve is fairly distinct toward the beak but nearly obsolete anteriorly, a variety of *Platystrophia* of medium size with the hinge line equalling or only slightly exceeding the general width of the shell, *Streptelasma rusticum*, and *Protarea vetusta*.

The same fauna, with the addition of *Schizolopha moorei* and *Streptelasma divaricans*, occurs 2 miles northwest of Versailles, where a branch of Cedar creek crosses the old road from Versailles to Osgood. It is seen also one mile northeast of Osgood south of the right of way formerly occupied by the Baltimore and Ohio Southwestern railroad, in a quarry. Here in addition to the fossils near Versailles are found *Crania scabiosa*, *Trematis millepunctata*, *Hebertella occidentalis* typical form, *Hebertella sinuata*, *Strophomena sulcata*, and *Rafinesquina alternata*. At the quarry the lower part of the section consists of limestone, which is equivalent to the upper part of the massive bed at Madison, and to the upper part of the exposure at the northern edge of Versailles. The overlying section, at least 13 feet thick, contains the fossils just enumerated. Immediately above occur layers of limestone in which are found structures which either are concretionary or are specimens of *Strephochetus* or *Girvanella*, varying between a quarter and a half inch in diameter. This layer is better exposed a quarter of a mile southwest along the same stream, nearer town. Immediately overlying this layer are thin limestones interbedded with clay, a section about 8 feet thick, containing *Hebertella sinuata*, *Platystrophia* Madison bed form, *Strophomena sulcata*, *Lophospira tropidophora*, *Protarea vetusta*, and *Streptelasma divaricans*. Several feet farther up, the top of the Madison bed consists of whitish limestone containing *Tetradium;* it evidently is the source of some of the pebbles in the Clinton limestone.

Six miles north of Osgood, a mile and a half northeast of Napoleon, the clays and thin limestones at the top of the Madison bed, exposed for a distance of at least 10 feet beneath the Clinton, contain *Rhynchotrema capax*, *Zygospira modesta*, and *Plectambonites sericea* in addition to species already mentioned. *Rafinesquina alternata* is rather abundant in the white limestone at the top of the section. *Streptelasma divaricans* is common at this horizon. *Streptelasma rusticum* is less abundant. *Hebertella* near *occidentalis* and the Madison bed form of *Platystrophia* are common here as elsewhere.

A mile north of Napoleon, a branch of Laughery creek exposes the top of the Madison bed, containing *Platystrophia acutilirita*, and a large form of *Plectambonites*, 25^{mm} in width

and strongly curved anteriorly in a geniculate manner, in addition to *Rhynchotrema capax* and other fossils,

The localities so far mentioned occur along the eastern line of outcrop of the Clinton, where the position of the fossiliferous layers, forming the top of the Madison bed, with reference to the *Tetradium* and *Columnaria* layers at its base, may be determined by following these beds along practically continues lines of exposure. The fossil lists indicate the presence in the upper part of the Madison bed of a considerable number of fossils hitherto considered as confined to lower divisions of the Richmond. There is evidently a recurrence of species usually found more abundantly in the Whitewater bed. If the existence of these species at the top of the Madison bed could not be proved by following up practically continuous exposures from Madison to the southeastern border of Ripley county, and then up the Laughery to Versailles, Osgood, and Napoleon, the occurrence of these species immediately beneath the Clinton in the Ripley island area, farther west, at a considerable distance from the continuous line of outcrop, would have been considered as indicative of the presence of one of the lower divisions of the Richmond, probably the Whitewater bed.

Five miles west of Napoleon, a mile southeast of the northwestern corner of Ripley county, on Honey creek, *Leptaena rhomboidalis*, *Strophomena vetusta*, the Richmond group form of *Cyclonema bilix*, and *Calymmene callicephala* are added to the list of species already mentioned as occurring at the top of the Madison bed. *Rafinesquina alternata* is found in the white limestone, 3 feet thick, forming the top of the Madison bed. Immediately below, *Calymmene callicephala*, *Plectambonites sericea*, and a strongly convex species of *Dalmanella*, only 13^{mm} wide, occur. The underlying beds, consisting of thin irregular limestones weathered into fragments and of greater quantities of clay, contain in addition to species already named from this locality, *Hebertella occidentalis*, *Hebertella* near *sinuata*, the Madison bed form of *Platystrophia*, *Platystrophia acutilirita*, *Strophomena sulcata*, the large strongly curved form of *Plectambonites*, *Rhynchotrema capax*, *Protarea vetusta*, *Streptelasma rusticum*, *Streptelasma divaricans*, and *Lophospira tropidophora*. The form of *Byssonychia* usually listed as *B. radiata* is present. The total thickness of the fossiliferous section here is 20 feet. This in itself would formerly have placed the reference of the Honey creek exposure to the top of the Madison bed in doubt, but the fossiliferous layers at the top of the Madison bed northeast of Osgood have an equal thickness, and the exposures at Osgood and near Napoleon carry practically the same fauna.

At Zenas, 5 miles southwest of the Honey creek exposures, the fossiliferous layers at the top of the Madison bed contain

Hebertella near *occidentalis*, and *Hebertella* near *sinuata*, *Platystrophia* Madison bed form, *Platystrophia acutilirita*, *Rafinesquina alternata*, *Ctenodonta cingulata*, *Schizolopha moorei*, and *Protarea vetusta*. Ten feet below the base of the Silurian section occurs limestone corresponding to the comparatively unfossiliferous limestone at the base of the quarry a mile northeast of Osgood, and to the top of the exposures at the north end of Versailles.

About 5 miles northwest of Zenas, and 6 miles west of the Honey creek locality, near the mouth of Painter creek, a mile and a half southeast of Westport, the top of the Ordovician, exposed in a vertical section 15 feet thick, contains the following fossils, which have been listed also from other localities farther east: *Dalmanella* small species with very convex brachial valves, *Hebertella* near *occidentalis*, *Hebertella sinuata*, Madison bed form of *Platystrophia*, *Platystrophia acutilirita*, *Leptaena rhomboidalis*, *Strophomena sulcata*, *Strophomena vetusta*, large form of *Plectambonites* strongly deflexed anteriorly, *Rhynchotrema capax*, *Trematis millepunctata*, *Protarea vetusta*, *Streptelasma rusticum*, and *Streptelasma divaricans*. *Dinorthis subquadrata*, not noted so far at this horizon, occurs also.

From Versailles the top of the Madison bed is exposed almost continuously along Big Graham creek as far as Benville. At New Marion the fossiliferous clayey beds overlying more solid limestones produce a section easily recognized as equivalent lithologically and faunally to that at the top of the Madison bed at Versailles. Four miles north of Benville, a mile and a half south of Nebraska, the banks of Otter creek expose a considerable section of Richmond rocks, about 60 feet thick, all of which is placed in the Madison bed, being regarded as a nearly complete section of the Madison bed at this locality. The fossils include the Madison bed form of *Platystrophia*, *Hebertella* near *sinuata*, and *Streptelasma divaricans*. At some horizons bryozoans are rather common, and their study may accomplish much in the future in confirming or combating the views here expressed, since the bryozoans are better horizon markers as a rule in the Cincinnati formations than the brachiopoda. In fact, the observations here recorded are direct evidence of the limited value of brachiopoda as horizon markers since most of the species here listed for the first time from the Madison bed have long been known from lower horizons in the Richmond.

Unconformity between Madison and Niagaran beds comparatively small.—The thickness of the Madison bed varies in an irregular manner in Indiana and western Kentucky, but in general there is a decrease in thickness on passing from Madison southward toward central Kentucky. In the opposite

direction, on passing from Kentucky toward Indiana, there is an increase of thickness and the observations so far made indicate that this increase continues northward from Madison toward the areas in the central part of Ripley and Jennings counties, in which the Clinton is absent. The two or three feet of fossiliferous strata at the top of the Madison bed at Madison appear to be the attenuated representatives of the much thicker fossiliferous beds at the top of the Madison bed in the central part of Ripley and Jennings counties. The Silurian, therefore, instead of resting upon lower beds of Richmond age in the region in which the Clinton is absent, actually rests on beds representing the latest deposits of Madison age so far studied. The small degree of unconformity between the top of the Ordovician and the base of the Silurian in the areas of Indiana, Ohio, and northern Kentucky, so far under investigation, is a most striking feature, considering the great lapse of time intervening between their disposition, as indicated by the great difference of their faunas.

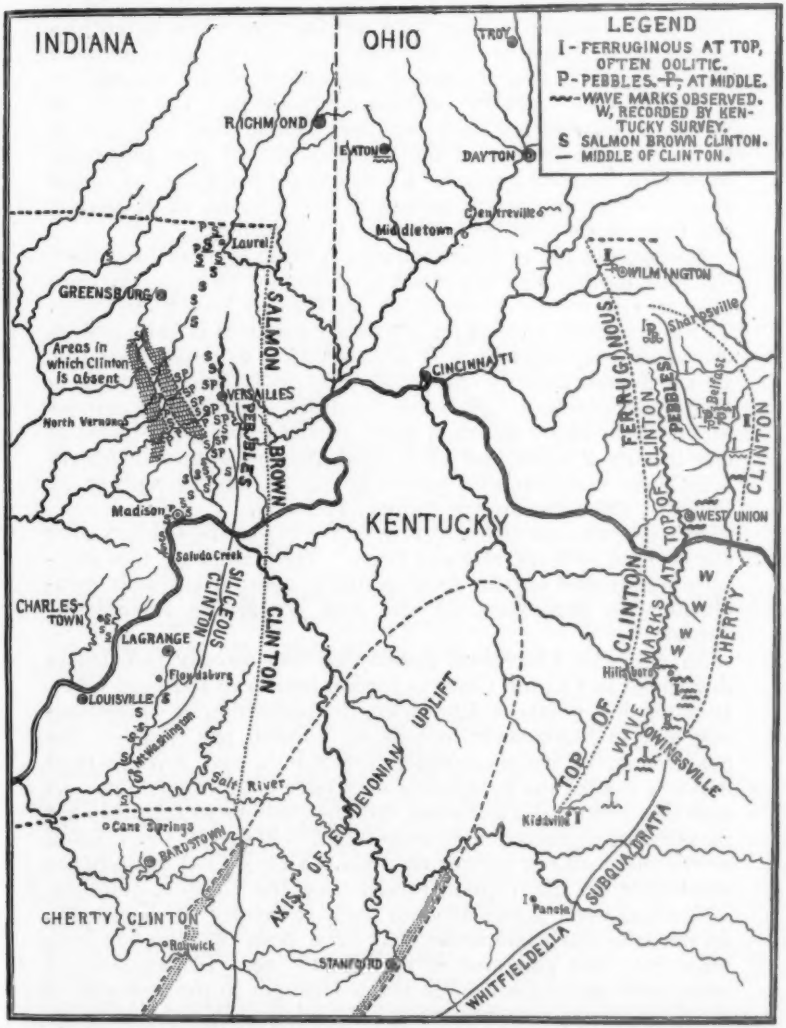
The *Lophospira hammelli–Holopea hubbardi* fauna may be traced from the southern margin of Ripley county to Floydsburg, in Kentucky, about 13 miles southeast of Charlestown landing. The fauna appears to be a depauperate one, a number of genera being represented by species of comparatively small size.

Parallelism of certain features shown by Clinton on opposite sides of the geanticline.—Along the same line of exposures, between the northwestern corner of Switzerland county and Lagrange, in Kentucky, the Clinton is usually quite thin, has a light red or pink instead of a salmon-brown color, and lithologically appears to be a dense siliceous limestone instead of a detrital limestone. Salmon-brown detrital phases are seen along this line but are less common. The area in which the siliceous phases of the Clinton are common is indicated on the accompanying map. Farther south, toward Mount Washington and for a short distance south of Salt river, in Kentucky, the salmon-brown, detrital phases of the Clinton are seen again. Northward, the salmon-brown phases of the Clinton extend as far as Laurel, Indiana.

The salmon-brown color of the Clinton in Indiana and western Kentucky appears to be due to the presence in very small quantity of some iron compound, sufficient to stain the calcite, but not visible to the eye, even under a microscope, as a substance distinct from the calcite. In Ohio and Kentucky, east of the Cincinnati geanticline, ferruginous layers occur at the top of the Clinton at many localities * within an area which

*Ohio Geol. Surv., iii, p. 442, 1878. Ohio Geol. Surv., Rept. for 1870, pp. 268, 269. Kentucky Geol. Surv., Rept. on Bath county, by W. N. Linney, p. 18, 1886. On the Clinton oolitic iron ores, this Journal, xli, 28, 1891.

has approximately the same northward and southward extension as the salmon-brown Clinton west of the geanticline. The



Map showing similar distribution of conglomeratic, ferruginous, and siliceous phases of the Clinton on opposite sides of the Cincinnati geanticline.

extent of this area is indicated on this plate. At the Rose Run Mining Company quarries, 4 miles east of Owingsville, the

ferruginous layers have a thickness of 3 feet and are sent to the iron furnaces along the Ohio river. The rock was originally a detrital limestone, more or less oolitic, but has in the course of time been replaced in part by a red iron ore which often preserves the structure of the fragments and of the more complete specimens of fossils, indicating the source of the material to which the rock owes its original composition. The rock was formerly quarried for use in smelters also at other localities in Kentucky and Ohio, but the development of iron industries elsewhere, in other states, on a much larger scale, has led to the abandonment of these workings in the Clinton of Kentucky and Ohio at all localities except at Owingsville.

Pebbles are found in the Clinton of Ohio at other localities* than the locality first described by Professor Orton. They are abundant at several horizons in the Clinton near Sharpsville. The area within which they are fairly common is indicated on the accompanying map. It is interesting to notice that this area is located directly east of the area in Indiana where pebbles are so common. At some localities in Ohio the pebbles are of much larger size than those usually found in Indiana; at one locality 2 miles east of Belfast, pebbles 4 to 8 inches in length are common, and quite a number attain a length of 12 inches. They are always strongly rounded.

Wave-marks are characteristic of the top of the Clinton over a wide area in Kentucky and Ohio. The extent of this territory is indicated on the accompanying map; it is almost coincident with the extent of the area containing ferruginous deposits.

In case the Cincinnati geanticline was already sufficiently developed in Clinton times to form a barrier in southern Ohio, Indiana, and adjacent Kentucky, the opposition of conglomeratic and salmon-brown deposits of Clinton age, west of the geanticline, to conglomeratic, ferruginous, and wave-marked deposits east of the geanticline may have little connection. In case this barrier did not exist, the observations so far made are in favor of a gradual diminution in thickness of the Clinton across the northern part of the field. They do not exclude the possibility of the former presence of the Clinton, thinning westward, even across the northern extremity of Kentucky. In this case the same cause may have been operative in both territories, east and west of the geanticline. The evidence of wave and current action is much stronger in the area east of the geanticline than westward. It is impossible to determine from the evidence at hand whether the few feet of Clinton strata west of the geanticline, in the region nearest the areas from which the Clinton is absent, are to be regarded as equiva-

*Journ. Geol., iii, pp. 16–30.

lent to the upper part of the Clinton east of the geanticline or as practically equivalent to the entire eastern section. So far no great difference has been noticed in the faunas in the upper and lower parts of the Clinton, east of the geanticline.

Additional notes on the development of the Cincinnati geanticline.—The pre-Meso-Devonic origin of the Cincinnati geanticline is shown best in Kentucky and Tennessee. Along the crest of the geanticline Devonian rocks rest on Ordovician formations, but both east and west of the crest the Devonian rests on successively younger beds of the Niagaran. The thinning out of the Louisville bed diagonally up the western flank of the geanticline from at least 60 feet at Louisville to nothing at Greensburg, and a similar thinning from the eastern parts of Bartholomew and Shelby counties eastward toward Greensburg, suggest similar conditions farther northward, in Indiana. At Greensburg,* according to Mr. J. A. Price, the sandy limestone of the Devonian rests directly upon the upper layers of the Laurel bed, even the Waldron bed being absent. The pre-Meso-Devonic age of the geanticline is indicated also in southern Ohio,† where, according to Professor Orton, neo-Devonian black slates or shales rest in succession on Niagaran, Cayugan, and Meso-Devonic limestones on proceeding from Highland county across Ross toward Franklin and Delaware counties. The presence of unconformable contacts between the Niagaran and Devonian in northern Indiana, at Delphi, Georgetown, and Kentland,‡ has been shown by Dr. E. M. Kindle. The evidence at hand, however, does not demonstrate the presence of the Indiana branch of the geanticline in pre-Devonic times.

The most interesting contribution of Dr. Kindle to the pre-Meso-Devonic geology of northern Indiana is the demonstration of the presence of strongly quaquaversal dips affecting Silurian rocks previous to the deposition of the Devonian. At some localities these dips suggested the presence of small domes. Quaquaversal dips, although usually of a much less pronounced character, are shown by Silurian strata also in central and southern Kentucky, and along the western flank of the geanticline in Tennessee. In fact, all the evidence so far accumulated indicates that while the Cincinnati geanticline in general shows a very simple structure, locally it may show strongly quaquaversal dips connected with subsidiary folds whose axes may be very divergent from the main axis of the geanticline. Owing to the low inclination of the rocks over the greater part of the area, these subsidiary folds attract much more attention than they would in a more highly inclined series of rocks.

* Indiana Geol. Surv., 24th Rept., pp. 87–90.
† Ohio Geol. Surv., Rept. for 1870, pp. 285–287.
‡ This Journal, vol. xv, p. 459, 1903.

Quaquaversal dips may have existed even before the deposition of the Niagaran. The variations in thickness of the Clinton in some parts of Kentucky and Tennessee are of an irregular character and can not be correlated in such a manner as to demonstrate the presence of the Cincinnati geanticline in pre-Niagaran times. The presence of wave-marks and pebbles in the Clinton of Ohio, Indiana, and northern Kentucky may have been connected with the existence in early Silurian times of very low irregular elevations of land of comparatively small extent in a very shallow expanse of sea covering wider areas. Similar wave-marks and pebbles are found at various elevations in the Richmond group in southwestern Ohio,* northern Kentucky, and southeastern Indiana.

The formation of the Cincinnati geanticline probably began with a general elevation of the sea bottom over wide areas, producing shallow waters. The irregular distribution at different levels of wave-marks and pebbles in rocks of Richmond age show that during late Ordovician times the waters were locally sufficiently shallow to bring the sea bottom within the range of action of waves, some parts being probably exposed to the air, at least at low tide. Along the western ranges of the Alleghanies there may have been a wide expanse of dry land, since the Richmond is absent eastward. Later there was a depression of the area eastward permitting the deposition there of the neo-Niagaran, but no deposits of this kind are known in the region of the Cincinnati geanticline, although their existence has been inferred in eastern and northern Ohio, below the cover of later rocks, from the records of drillers.

During early Niagaran times the depression appears to have progressed sufficiently to permit of the deposit over wide areas of the Clinton. There is no evidence, however, that the Clinton ever reached the western half of Indiana and the adjacent part of Kentucky. During the Clinton irregular shallow water conditions prevailed in certain areas. The Osgood clays may formerly have extended across the region of the present Cincinnati geanticline. The moderate quaquaversal dips of the earlier part of the Niagaran were followed in some areas by the stronger quaquaversal dips of the later Silurian. Just when the changes in level involved resulted in the production of the initial stages of the axis of the present Cincinnati geanticline is unknown, but it probably preceded Devonian times since in the Meso-Devonian the Cincinnati geanticline had attained considerable development.

While the origin of the Cincinnati geanticline in pre-Meso-Devonic times can be demonstrated, it owes its present proportions chiefly to later orogenic processes. In Ohio, the labors of Professor Orton have demonstrated to what a remarkable extent the present development of the geanticline was depend-

* Journ. Geol., 1895, pp. 6, 7, 9-11.

ent upon post-Meso-Devonic folding. His sections from Bryan to Sandusky,* and from Bryan to Bucyrus show this clearly, and similar sections collated from his notes on the well records of more southern areas indicate to what a large extent the geanticline owes its importance to post-Meso-Devonic folding. The strong eastward dip of the neo-Devonic black shales and of the Waverly indicate that a great part of this folding was probably of post-Mississippian age. Similar facts are observed also along the Ohio river, west of the crest of the geanticline, near Louisville,† where it is evident that the rapid westward dips affecting the neo-Devonic black shale and the Mississippian strata are largely instrumental in giving prominence to the geanticline. Similar facts are observed also in Kentucky and Tennessee. The elevation of the Cincinnati geanticline was therefore a process, probably more or less interrupted, but continuing through long geological ages, the greater part of the development of this fold having taken place in post-Devonian, and probably in post-Mississippian times.

Approximate relationship of Clinton and Osgood Faunas of Indiana to the lower Niagaran Faunas of New York.

The Osgood bed introduces the typical Niagaran fauna. Here are found the first species of *Gomphocystites*, *Holocystites*, *Stephanocrinus*, *Pisocrinus*, and *Lecanocrinus;* here are found the first specimens of *Pentamerus oblongus*, *Rhynchotreta cuneata americana*, typical *Camarotoechia neglecta*, *C. indianensis*, *Atrypa reticularis*, *Spirifer radiatus*, *Sp. eudora*, *Sp. niagarensis*, *Cyrtea exporrecta*, *C. myrtea*, *Nucleospira pisiformis*, *Whitfieldella cylindrica*, *Atrypa calvani*, *Orthoceras amycus*, *O. medullare*, and *Dalmanites limulurus*.

The Clinton of Ohio, Indiana, and Kentucky contains a fauna so different from that of New York and other eastern localities that the existence of some sort of a barrier between these two areas has been suggested. The attempt formerly to identify western Clinton species by means of the plates in the second volume on the paleontology of New York has resulted in various errors not yet corrected. It is certain that the species identified as *Strophonella patenta* from the Clinton of Ohio is distinct from the type species described from New York and the name *Strophonella daytonensis* is here suggested for the same. The identification of *Phacops trisulcatus* rests upon very unsatisfactory grounds. Such names as *Cornulites distans*, *Orthoceras clavatum*, *O. virgulatum*, *Conularia niagarensis*, and *Murchisonia subulata*, can have little value

* Ohio Geol. Surv., vi, 1888, pp. 48, 134, 183, 305. Am. Geol. 1891, pp. 105–108.

† Indiana Geol. Surv., 25th Rept., map, p. 349; Silver Creek Hydraulic limestone, by C. E. Siebenthal; also 26th Rept., 1903, maps, pp. 235, 261; Geological section across southern Indiana, by J. F. Newsom.

until much better representatives of the type species are secured. *Sphaerexochus pisum* is a species of *Deiphon* and is closely related to *D. forbesi.* Representatives of genera more abundantly represented in the Ordovician occur in the Clinton, such as *Platystrophia daytonensis, Pl. reversata, Hebertella fausta, H. daytonensis, Cyclonema daytonensis.* A form of *Plectambonites* allied to *Pl. sericea* is the only species passing from the Ordovician into the Clinton with little change; the more distinct form, *Pl. transversalis,* however, is much more common. The identification of the lowest Silurian bed in the area of the Cincinnati geanticline as Clinton does not rest so much upon the identity of faunas at the two localities as upon the presence of a few species which are identical, a few which are closely allied, the general absence of species which may be regarded as most typical of the Rochester shale of New York, and a general facies which suggests that the western fauna represents a somewhat similar stage in development.

In New York, some of the species, which in the area of the Cincinnati geanticline are not found beneath the Osgood bed, occur in the lenses at the top of the Clinton; some of them occur even in the upper beds of the Clinton. As far as may be determined from the evidence at hand, the Osgood bed contains a part of the fauna of the lenses at the top of the Clinton and of the lower half of the Rochester shales in New York, a part of this fauna beginning at the top of the Clinton in that state; while the Clinton of Ohio, Indiana, and Kentucky appears to have attained the stage of development equivalent to that of the Clinton of New York, below the lenses, but does not contain such species as *Pentamerus oblongus, Atrypa reticularis, Spirifer radiatus, Sp. niagarensis,* which in the west begin their existence in the Osgood bed. The faunal elements of the Clinton in the two areas are different and a more exact comparison is at present impossible.

Lists of Niagaran Fossils.

The best lists of the fossils of the various subdivisions of the Cincinnatian strata in Ohio, Indiana, and adjacent Kentucky are those published by Mr. J. M. Nickles in the Journal of the Cincinnati Society of Natural History, volume xx, No. 2, 1902.

A list of the fossils identified from the Clinton of Indiana was published in "Silurian and Devonian limestones of Tennessee and Kentucky," a Bulletin of the Geological Society of America, in 1901, on pages 438–441.

Osgood Fossils.

In the following list the names of the localities Osgood, New Marion, and Big Creek are indicated by the letters O, N, and B following immediately after the name of the species. Unless

otherwise recorded, the crinoids and cystids are from Big Creek:

Receptaculites ——, B.
Ceramopora imbricata. O,N,B.
Mesotrypa milleri, O.
Idiotrypa parasitica, O.
Callopora elegantula, O.
Pachydictya crassa, O.
Duncanella borealis, O,N.
Favosites forbesi, O,B.
Favosites cristatus, B.
Striatopora flexuosa, O.
Striatopora sessile on crinoid stems, O.
Thecia major, O.
Plasmopora ——, O.
Allocystites hammelli, Rikers Ridge.
Caryocrinus ellipticus, O.
Caryocrinus indianensis.
Caryocrinus hammelli.
Caryocrinus ornatus.
Gomphocystites indianensis.
Holocystites abnormis, Madison?
adipatus.
affinis.
amplus, Big Creek?
asper.
brauni.
benedicti.
bacculus.
canneus.
colletti.
commodus.
cylindricus.
dyeri, Osgood.
elegans.
faberi.
globosus.
gorbyi.
gyrinus.
hammelli.
indianensis.
madisonensis.
ornatissimus.
ornatus.
ovatus, Madison?
papulosus.
parvulus.
parvus.
perlongus, O.
plenus.
rotundus, O.
scitulus.
spangleri.
spaeroidalis.
splendens.
subglobosus, Big Creek?
subovatus.
subrotundus, O.
tumidus.
turbinatus, O.
ventricosus, O.
wetherbyi, O.
wykoffi.
Pisocrinus gemmiformis, O,N,B, Nebraska.
Stephanocrinus cornetti, B, Rikers Ridge.
deformis.
elongatus, O,B.
hammelli, O.
obpyramidalis.
osgoodensis, O.
quinquepartitus.
Orthis flabellites, O,N,B, Nebraska.
Platystrophia biforata, Nebraska.
Dalmanella elegantula, O,N.
Rhipidomella hybrida, O,N, Nebraska.
Leptaena rhomboidalis. N,B.
Plectambonites transversalis, O,N,B, Nebraska.
Rhynchotreta cuneata-americana, O.
Camarotoechia neglecta, N,B.
Camarotoechia indianensis, O.
Atrypa reticularis, O,N,B.
Spirifer radiatus, N,B.
Spirifer eudora, N.
Spirifer niagarensis, N,B.
Cyrtia exporrecta, N,B.
Cyrtia myrtea (meta?), N.
Nucleospira pisiformis, N.
Whitfieldella cylindrica, N.
Whitfieldella quadrangularis, B.
Atrypa calvani, B.
Diaphorostoma niagarense, O,N,B.
Orthoceras simulator, B.
Orthoceras amycus, O,B.
Orthoceras medullare, B.
Calymmene nasuta, O,B.
Dalmanites limulurus, O.
Illaenus ——, O,B.

In Ohio Pentamerus oblongus occurs in the Dayton limestone, equivalent to the base of the Osgood bed.

Laurel Fossils.

Unless otherwise stated, the fossils are from St. Paul.

Amplexus	cinctutus, Miller.
Favosites	spongilla, Rominger.
Streptelasma	spongiaxis, Rominger.
Striatopora	gorbyi, Miller.

Plasmopora	follis, Milne-Edwards.
Plasmopora	scita ? Milne-Edwards.
Aethocystites	sculptus, Miller.
Allocrinus	benedicti, Miller.
Calceocrinus	indianensis, Miller.
Callicrinus	beachleri, Wachsmuth + Springer.
Caryocrinus	ellipticus, Miller + Gurley.
Cyclicocrinus	canaliculatus, Miller.
Cyclicocrinus ?	indianensis, Miller + Gurley.
Cyphocrinus	gorbyi, Miller.
Emperocrinus	indianensis, Miller + Gurley.
Gazacrinus	inornatus, Miller.
Holocystites	pustulosus, Miller : a few miles from Waldron, Indiana, some distance below the range of Waldron beds.
Hyptiocrinus	typus, Wachsmuth + Springer.
Idiocrinus	elongatus, Wachsmuth + Springer.
Idiocrinus	ventricosus, Wachsmuth + Springer.
Indianocrinus	punctatus, Miller + Gurley.
Macrostylocrinus	indianensis, Miller + Gurley.
Mariacrinus	aureatus, Miller.
Mariacrinus	granulosus, Miller.
Melocrinus	equalis, Miller.
Melocrinus	oblongus, Wachsmuth + Springer.
Melocrinus	parvus, Wachsmuth + Springer.
Pisocrinus	baccula, Miller + Gurley.
Pisocrinus	globosus, Ringueberg.
Saccocrinus	benedicti, Miller.
Saccocrinus	howardi, Miller.
Saccocrinus	umbrosus, Miller + Gurley.
Stribalocystites	gorbyi, Miller.
Stribalocystites	tumidus, Miller.
Stribalocystites	spheroidalis, Miller + Gurley.
Zophocrinus	howardi, Miller.
Spirifer	radiatus, Sowerby. From Madison.
Cyrtoceras	howardi, Miller.
Cyrtoceras	indianense, Miller.
Orthoceras	annulatum,
Orthoceras	imbricatum,
Orthoceras	subcancellatum,
Cyrtoceras	elrodi, White.
Lichas	byrnesanus, Miller + Gurley. From neighborhood of Madison.
Lichas	hanoverensis. Miller + Gurley. From Hanover.

The fauna of the Waldron bed was described by Hall in the eleventh annual report of the Indiana Geological Survey, this being a republication of various papers in the Transactions of the Albany Institute and the New York State Museum Reports.

The brachiopod and gasteropod fauna of the Louisville bed was described by Henry Nettelroth in Kentucky Fossil Shells of the Silurian and Devonian Rocks, 1889, a publication of the Kentucky Geological Survey. The corals of the Louisville bed were figured by W. J. Davis, in Kentucky Fossil Corals of the Silurian and Devonian Rocks, 1885. In these publications all fossils cited from Silurian rocks, with the possible exception of *Zaphrentis patula*, *Z. socialis*, and *Z. patens*, come from the Louisville bed.

Dayton, Ohio.

Art. XXXVII.—*A Crystallographic Study of Millerite;* by Charles Palache and H. O. Wood.

The crystallographic character of millerite was first defined by Miller in 1835 in a paper* interesting historically as containing the first presentation of his index system of notation. He determined the forms o, (0001), b, (10$\bar{1}$0), k, (21$\bar{3}$0), e, (01$\bar{1}$2), r, (10$\bar{1}$1), r_1, (01$\bar{1}$1) and v, (50$\bar{5}$2) on crystals without natural terminations, but which had been broken across. And on a single terminated crystal with dull faces, he found the form t, (03$\bar{3}$1) by contact measurement. The angle $o \wedge r = 20° 50'$ was the average of several readings, and led to the axial ratio $a : c = 1 : 0{\cdot}3295$ which is at present accepted. In the lack of details as to faces and measurements, we are forced to conclude that he, at that time, considered five kinds of cleavage present, parallel to o, e, r, r_1, and v. In his Mineralogy† the matter is presented somewhat differently. The prism a, (11$\bar{2}$0) is added, and instead of v, (50$\bar{5}$2), is given e_1, (10$\bar{1}$2), without explanation. He also states that possibly the appearance of cleavage on both positive and negative rhombohedrons, r and r, and e and e_1, is due to concealed twinning on the vertical axis. The occurrence of the rhombohedron v, (50$\bar{5}$2), is therefore left in doubt, and cleavage parallel to the base and to the two rhombohedrons r and e is indicated.

In 1892, Laspeyres‡ described beyrichite and paramorphs of millerite after beyrichite. He concludes that all millerite is derived from beyrichite, and that for the crystals of both minerals examined, the crystallographic characters are identical. The forms observed were b, (10$\bar{1}$0), a, (11$\bar{2}$0), i, (41$\bar{5}$0), r, (10$\bar{1}$1) and e, (01$\bar{1}$2); the two last both as cleavages and as dull terminal faces, and each in apparently positive and negative positions through twinning about the vertical axis. The axial ratio $a : c = 1 : 0{\cdot}3277$ was derived from measurement of the cleavage rhombohedron.

The form i, (41$\bar{5}$0), is based on poor measurements, the average differing by more than a degree from the calculated value, and therefore is to be regarded as very doubtful.

In 1893, the same author in a paper§ on the various nickel deposits of the Rhine, describes various occurrences of millerite. On specimens from two localities, terminated but not measurable crystals were observed, on which c, (0001) and r, (10$\bar{1}$1) were present together with the ordinary prism forms.

The list of forms known on millerite up to the present time

* Phil. Mag., vi, 104, 1835. † Phillips Mineralogy, 163, 1852.
‡ Zeitschr. f. Kryst., xx, 535, 1892.
§ Das Vorkommen und die Verbreitung des Nickels im Rheinischen Schiefergebirge. Verh. Nat.-hist. Ver. Rheinl., l, 142, 1893.

reads then as follows: *b*, $(10\bar{1}0)$, *a*, $(11\bar{2}0)$, *k*, $(21\bar{3}0)$, *c*, (0001), *e*, $(01\bar{1}2)$, *r*, $(10\bar{1}1)$, and doubtful *i*, $(41\bar{5}0)$, *v*, $(50\bar{5}2)$ and *t*, $(03\bar{3}1)$. Cleavage parallel to *r* and *e* is established.

In the Mineral Cabinet of Harvard University is a suite of specimens derived from the collection of Prof. J. D. Whitney, illustrating the occurrence of millerite, and its associated minerals, at the old Nickel Mine at Orford, Province of Quebec. The beauty, perfection and unusual size of these crystals of millerite led to their study, and examination of the literature revealed the fact that no detailed description of this occurrence existed. Such a description is here presented, since the study of this material has added largely to our knowledge of the crystallography of millerite.

The nickel deposit occurs on the east side of Brompton Lake in Orford Township, Province of Quebec. It consists, as may be gathered from scattered notes in the Canadian Survey Reports, of a large vein chiefly composed of granular white calcite which traverses serpentine. Mingled with the calcite and especially abundant near the vein walls are considerable masses of a bright green chrome-garnet in granular aggregates, and of a light colored diopside, both granular and in long stout crystals. Millerite in grains and prisms is scattered irregularly through the vein matter. The deposit has long been known, and it seems to have been worked for a short time in the seventies, but was abandoned soon, the nickel content of the vein material, less than one per cent, having been too small to pay for extracting.

The specimens in hand consist chiefly of chrome-garnet, partly in granular masses, partly in aggregates of minute individual crystals held together by a cement of calcite, the removal of which with acid causes the mass to crumble. In the latter case, and indeed wherever the garnet is in contact with the calcite, it is in sharp crystals, with the dodecahedron as the dominant form. On a few crystals the dodecahedron edges were truncated by planes, which on measurement proved to be those of two hexoctahedrons, (358) and (459), the latter new to garnet. The faces were extremely narrow and the reflections poor, hence the considerable variations in the position of the faces.

Symbol. Miller.	G_1.	Observed angles (av.). ϕ	ρ	No. of faces.	Calculated angles. ϕ	ρ
(358)	$\frac{3}{5}$ $\frac{5}{8}$	32° 12′	35° 37′	6	30° 58′	36° 05′
(385)	$\frac{3}{8}$ $\frac{8}{5}$	21° 00′	60° 08′	5	20° 33′	59° 40′
(583)	$\frac{5}{3}$ $\frac{8}{3}$	31° 21′	71° 42′	5	32° 00′	72° 21′
(459)	$\frac{4}{9}$ $\frac{5}{9}$	39° 16′	35° 26′	6	38° 39′	35° 26′
(495)	$\frac{4}{5}$ $\frac{9}{5}$	23° 36′	62° 43′	5	23° 58′	63° 05′
(594)	$\frac{5}{4}$ $\frac{9}{4}$	28° 46′	68° 17′	5	29° 03′	68° 46′

The garnet is green in color, varying from a yellowish tone in massive specimens to a deep emerald-green in the sparkling transparent crystals.

The following analysis by T. Sterry Hunt is taken from Dawson, Geology of Canada, p. 497.

	I.	II.
SiO_2	36·65	
Al_2O_3	17·50	
Cr_2O_3	6·20	6·93
FeO	4·97	4·80
CaO	33·20	33·29
MgO	0·81	
Volatile	0·30	
Total	99·63	

The analysis shows that the garnet is ouvarovite, but with a very small proportion of chromium.

Specks of chromite are embedded in the garnet, in places quite abundantly.

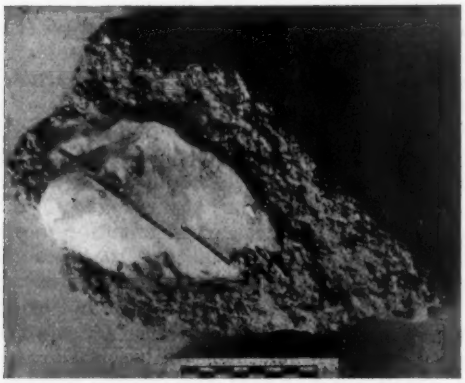
The pyroxene is yellow-gray or pale green, and is either in isolated crystals embedded in calcite, in granular masses consisting almost wholly of this mineral, or in minute crystals implanted on the surface of garnet aggregates. The crystals are prismatic and are often large, up to six or more inches in length. The pinacoids *a*, (100) and *b*, (010) are dominant, and narrow faces of the prisms *m*, (110) and *i*, (130) are always present. These forms always have smooth and brilliant faces; the terminating planes, on the contrary, are always dull and measurements could be obtained only with great difficulty. The forms *p*, ($\bar{1}01$) and *u*, (111) are always present and occasionally minute faces of *c*, (001), *s*, ($\bar{1}11$), and several other pyramids not corresponding to established pyroxene forms were noticed. Twins on the common pyroxene law, (100) the twinning plane, are common. No analysis of this material could be discovered.

The calcite vein-filling is snow-white and very coarsely granular, individual cleavage rhombs up to three inches across being at hand. It is characterized by an extreme development of pressure-twinning parallel to *e*, ($01\bar{1}2$), so that a parting parallel to the negative rhombohedron with smooth reflecting surfaces scarcely inferior to those of the cleavage, is often obtained. The occurrence of this twinning-parting in the calcite is especially noteworthy, since this identical structure is also developed in the millerite, as will be shown presently.

Millerite occurs scattered through the massive garnet, more abundantly at the boundary between garnet or pyroxene and calcite, and finally wholly embedded in calcite. The aggre-

gates of garnet, pyroxene, calcite and millerite are such that no sequence of formation can be recognized, all appearing rather to have crystallized together. When in the massive garnet the millerite is in grains of small size. On contact surfaces as developed by removal of calcite with acid, the millerite is either in short stout prisms loosely implanted on the garnet and projecting into the calcite with developed terminal planes; or it is in long and relatively slender striated prisms, which lie parallel to the garnet surface and adhere to it closely, being bent, twisted and contorted in extraordinary fashion as though, after formation, the crystals had been pressed down

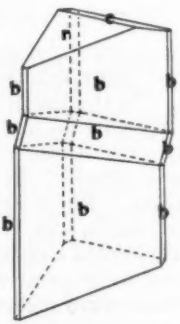
1



to fit all the irregularities of the uneven underlying surface. Their appearance is unique; and no explanation of their probable mode of formation has occurred to us. So soon as the millerite passes from the immediate contact zone, and is embedded in calcite, the crystals are free from these extreme dislocations; the long prisms are sometimes warped and knicked by pressure-twinning, but entirely lose the crushed appearance as described above. Crystals may be seen crushed and twisted where they lie prone, but which pass into the calcite and become immediately relatively straight and plane-surfaced. The millerite crystals in the calcite reach dimensions quite unusual for this mineral. Prisms two millimeters in diameter and four centimeters long are present among our specimens. They are said to reach a length of eight centimeters or more (three inches). These prisms are generally sharply trigonal in outline, the three faces bright and polished

and the angles rounded and striated. No terminated crystals of this type were found, all showing terminal planes of cleavage only. A striking and hitherto unknown character of the mineral was first seen and interpreted on one of the triangular cleavage fragments shown in fig. 2. This crystal consists of three segments, the upper and lower ones parallel, the intermediate portion in twin position to the other two, a face of the form *e*, $(01\bar{1}2)$, being the twinning plane. $10\bar{1}1 \wedge 10\bar{1}0$ (twin), measured 21° 23′½, calculated 21° 25′. The form of the twin suggested that it might be due to the presence of a gliding plane and produced by pressure; and experiment soon showed this to be the case. A crystal held firmly and subjected to shearing stress can be offset readily. The same

2



result may be obtained by placing the crystal on a yielding support, and pressing upon it transversely with a knife-edge, in which case a fine lamella is thrown into twin position. The gliding takes place with equal ease, of course, parallel to each of the three rhombohedron planes. With very slender crystals it is difficult to produce the twinning, the pressure breaking the brittle substance to pieces, and this probably accounts for the failure to recognize this remarkable property of millerite hitherto. Careful tests on millerite crystals from a number of localities were uniformly successful, and showed it to be a general property of the mineral. In view of the ease with which this gliding twinning can be obtained, and of the striking effect produced, it seems that millerite should take equal rank with calcite as an illustration of this interesting phenomenon.

Highly perfect cleavage is present parallel to the unit rhombohedron, *r*, $(10\bar{1}1)$, and also to the negative rhombohe-

dron, *e*, $(01\bar{1}2)$, the latter identical with the gliding plane. No difference in the quality of the two cleavages can be detected, and planes of both are generally produced when a crystal is broken. No indication of a cleavage parallel to a prism, such as Laspeyres found in millerite derived from beyrichite, was observed.

The Orford millerite is characterized by brilliant metallic luster, and a pale brass-yellow color which is quite constant on all planes and surfaces of the mineral. Laspeyres' conclusion mentioned above, that all millerite is derived from beyrichite, a conclusion based largely on an observed color change, finds absolutely no support in this occurrence.

No analysis of the millerite was made. Careful qualitative tests for copper and cobalt gave only negative results, and it is probably very nearly pure nickel sulphide.

Crystallography.

A number of crystals showing natural terminal planes were obtained from several of the specimens by removal of calcite with hydrochloric acid. In the majority of cases, the crystals were attached to the matrix by an end and thus showed but a single termination; two or three crystals of poor quality were found which were attached by prism faces and thus showed both terminations. These crystals were in all cases small, from 2 to 5^{mm} in length, and from $0{\cdot}1^{mm}$ to 1^{mm} in diameter. In habit they vary from slender prisms to short stubby crystals of diameter equal to or greater than their length.

In all thirty-two crystals were measured. Of these twenty-eight were measured completely in the two-circle goniometer. Four were measured for special angles.

From the data obtained in measurement, the following forms were established, those marked with a star being new: *b*, $(10\bar{1}0)$, *a*, $(11\bar{2}0)$, *k*, $(21\bar{3}0)$, *d*, $(72\bar{9}0^*)$, *r*, $(10\bar{1}1)$, *v*, $(50\bar{5}2)$, *p*, $(02\bar{2}1^*)$, *s*, $(21\bar{3}1^*)$ and *u*, $(\bar{4}\bar{1}53^*)$. Doubtful values for the following forms were found. These need confirmation for their establishment. *i*, $(41\bar{5}0)$, *f*, $(9{\cdot}4{\cdot}\bar{1}\bar{3}{\cdot}0^*)$, *g*, $(31{\cdot}13{\cdot}\bar{4}\bar{4}{\cdot}0^*)$, *t*, $(03\bar{3}1)$, *h*, $(30\bar{3}1^*)$, *x*, $(40\bar{4}1^*)$, *j*, $(50\bar{5}1^*)$, *l*, $(09\bar{9}1^*)$, *m*, $(0{\cdot}18{\cdot}\bar{1}\bar{8}{\cdot}1^*)$, *n*, $(52\bar{7}6^*)$, *o*, $(7{\cdot}4{\cdot}\bar{1}\bar{1}{\cdot}9^*)$, *q*, $(51\bar{7}4^*)$, and *w*, $(42\bar{6}5^*)$. The only forms satisfactorily established which we did not find on the Orford mineral are the base *c*, (0001), which was observed by both Miller and Laspeyres, and the rhombohedron *e*, $(01\bar{1}2)$ observed by the latter.

Measurements were obtained from the dominant rhombohedrons from which a satisfactory axial ratio could be calculated.

For r, $(10\bar{1}1)$

10	readings,	very good	signals,	average	value of	$\rho = 20° 43'{\cdot}4$
11	"	good	"	"	"	$\rho = 20° 42'{\cdot}8$
4	"	fair	"	"	"	$\rho = 20° 43'{\cdot}5$
12	"	poor	"	"	"	$\rho = 20° 41'{\cdot}5$
37	"	all sorts	"	"	"	$\rho = 20° 42'{\cdot}6$

For p, $(02\bar{2}1)$

3	readings,	very good	signals,	average	value of	$\rho = 37° 07' \frac{1}{3}$
6	"	good	"	"	"	$\rho = 37° 03' \frac{1}{2}$
6	"	fair	"	"	"	$\rho = 37° 07' \frac{1}{2}$
6	"	poor	"	"	"	$\rho = 37° 17' \frac{1}{3}$
12	"	very poor	"	"	"	$\rho = 37° 12' \frac{1}{3}$
Mean of 24	"	selected	"	"	"	$\rho = 37° 09'{\cdot}0$
Mean of 15	"	best	"	"	"	$\rho = 37° 05'{\cdot}8$

(The word selected as used above means that, using the averages found in the columns above, the whole number of readings whose signals were very good, good and fair was summed with half the number of readings whose signals were poor and very poor, and the general average then taken, weighted in this manner to avoid giving undue influence to the relatively large number of inferior readings.)

Using the formula $pp_0\sqrt{3} = \tan \rho$ and the above values, we obtain,

$$p=1, \quad \rho = 20° 42'{\cdot}6, \quad p_0 = 0{\cdot}21828$$
$$p=2, \quad \rho = 37° 05'{\cdot}8, \quad p_0 = 0{\cdot}21830.$$

Taking the value of $p_0 = 0{\cdot}2183$ we have from the relation

$$c = \tfrac{3}{2} p_0, \quad a : c = 1 : 0{\cdot}3274.$$

This value of p_0, which is based on a large number of measurements, is probably to be given preference over Miller's value; it is exceedingly near the value of p_0 for beyrichite found by Laspeyres.

Found, millerite	$p_0 = 0{\cdot}2183$
Miller ."	$p_0 = 0{\cdot}2197$
Laspeyres, beyrichite	$p_0 = 0{\cdot}2185$

Accordingly a table of angles based on the new value is presented to replace that given in Goldschmidt, Winkeltabellen, p. 242. It contains the new forms, and in a supplement those doubtful ones not yet fully established. This constitutes Table I.

TABLE I—MILLERITE.

Hexagonal. Rhombohedral-hemihedral.

$c=0{\cdot}32745$ $lgc=9{\cdot}51514$ $lga_0=0{\cdot}72341$ $lgp_0=9{\cdot}33905$ $a_0=5{\cdot}2895$ $p_0=0{\cdot}2183$. (G_2)

Number.	Letter.	Symb. G_2.	Bravais.	ϕ.	ρ.	ξ_0.	η_0.	ξ.	η.	$\frac{x}{x:y}$ Prisms	y.	$\frac{d}{=tg\,\rho}$.
1	*c*	0	0001	0° 00′	0° 00′	0° 00′	0° 00′	0° 00′	0° 00′	0	0	0
2	*b*	∞	$10\bar{1}0$	30° 00′	90° 00′	90° 00′	90° 00′	30° 00′	60° 00′	0·5773	∞	∞
3	*a*	∞0	$11\bar{2}0$	0° 00′	90° 00′	0° 00′	90° 00′	0° 00′	90° 00′	0	∞	∞
4	*k*	4∞	$21\bar{3}0$	10° 53′	90° 00′	90° 00′	90° 00′	10° 53′	79° 06′	0·1924	∞	∞
5	*d*	$\frac{11}{5}\infty$	$72\bar{9}0$	17° 47′	90° 00′	90° 00′	90° 00′	17° 47′	72° 13′	0·3207	∞	∞
6	*r*	1	$10\bar{1}1$	30° 00′	20° 42′	10° 42′	18° 08′	10° 11′	17° 50′	0·1890	0·3274	0·3781
7	*v*	$\frac{5}{2}$	$50\bar{5}2$	30° 00′	43° 23′	25° 18′	39° 18′	20° 05′	36° 30′	0·4726	0·8186	0·9452
8	*p*	−2	$02\bar{2}1$	30° 00′	37° 06′	20° 42′	33° 13′	17° 33′	31° 29′	0·3781	0·6544	0·7562
9	*e*	$-\frac{1}{2}$	$01\bar{1}2$	30° 00′	10° 42′	5° 24′	9° 18′	5° 20′	9° 15′	0·0945	0·1634	0·1890
10	*s*	41	$21\bar{3}1$	10° 53′	45° 00′	10° 42′	44° 29′	7° 41′	43° 59′	0·1890	0·9823	1·0003
11	*u*	−21	$4\bar{1}53$	19° 06′	38° 00′	10° 42′	28° 37′	9° 25′	28° 12′	0·1890	0·5457	0·5775
?	*i*	2∞	$41\bar{5}0$	19° 06′	90° 00′	90° 00′	90° 00′	19° 06′	70° 53′	0·3464	∞	∞
?	*f*	$\frac{17}{9}\infty$	$9{\cdot}4{\cdot}\bar{1}3{\cdot}0$	12° 31′	90° 00′	90° 00′	90° 00′	12° 31′	77° 28′	0·2220	∞	∞
?	*g*	$\frac{19}{6}\infty$	$31{\cdot}13{\cdot}\bar{4}\bar{4}{\cdot}0$	13° 17′	90° 00′	90° 00′	90° 00′	13° 17′	76° 42′	0·2361	∞	∞
?	*h*	3	$30\bar{3}1$	30° 00′	48° 36′	29° 33′	44° 29′	22° 01′	40° 31′	0·5671	0·9823	1·1343
?	*t*	−3	$03\bar{3}1$	30° 00′	48° 36′	29° 33′	44° 29′	22° 01′	40° 31′	0·5671	0·9823	1·1343
?	*x*	4	$40\bar{4}1$	30° 00′	56° 31′	37° 06′	52° 38′	24° 39′	46° 15′	0·7562	1·3098	1·5724
?	*j*	5	$50\bar{5}1$	30° 00′	62° 07′	42° 23′	58° 35′	26° 14′	49° 57′	0·9452	1·6372	1·8905
?	*l*	−9	$09\bar{9}1$	30° 00′	73° 37′	59° 33′	71° 15′	28° 40′	56° 11′	1·7014	2·9470	3·4030
?	*m*	−18·18	$0{\cdot}18{\cdot}\bar{1}8{\cdot}1$	30° 00′	81° 38′	73° 37′	80° 22′	29° 41′	59° 02′	3·4030	5·8940	6·8060
?	*n*	$\frac{2}{5}\,\frac{1}{2}$	$5{\cdot}2{\cdot}\bar{7}{\cdot}6$	13° 59′	21° 29′	5° 24′	20° 54′	5° 08′	20° 44′	0·0945	0·3820	0·3935
?	*o*	$\frac{5}{2}\,\frac{1}{2}$	$7{\cdot}4{\cdot}\bar{1}\bar{1}{\cdot}9$	8° 57′	22° 03′	3° 36′	21° 48′	3° 21′	21° 46′	0·0630	0·4002	0·4051
?	*q*	$-\frac{5}{3}\,\frac{5}{4}$	$\bar{6}\bar{1}74$	22° 24′	31° 47′	13° 18′	29° 49′	11° 35′	29° 09′	0·2363	0·5730	0·6198
?	*w*	$\frac{8}{5}\,\frac{2}{5}$	4265	10° 53′	21° 48′	4° 19′	21° 27′	4° 01′	21° 23′	0·0756	0·3929	0·4001

Table II shows the character of the combinations observed on the measured crystals, the numbers under each letter indicating the number of faces of that form found on the given crystal.

TABLE II.

	b	*a*	*k*	*d*	*r*	*p*	*v*	*s*	*u*
A	6	1	.	.	2	.	.	.	.
1	6	.	1	1	1	1	.	.	.
2	6	2	3	2	2	1	.	.	6
3	6	2	1	2	3	3	.	.	.
4	6	2	.	2	3	.	.	.	6
5	3	1	.	.	3	1	.	.	1
6	4	.	.	.	3	3	.	.	.
7	6	6	2	.	3	.	.	.	3
8	6	.	.	.	3	3	.	.	.
9	6	4	.	4	3	3	.	.	1

	b	*a*	*k*	*d*	*r*	*p*	*v*	*s*	*u*
12	6	4	.	1	3	.	.	.	.
13	6	2	.	.	.	.	.	.	.
14	4	.	.	.	.	3	.	.	1
15	*x*	.	.	.	*x*	*x*	.	.	*x*
16	4	.	.	.	3	3	2	.	.
17	3	.	.	.	3	3	.	.	.
18	3	.	.	.	3	3	1	.	.
19	1	.	.	1	3	1	.	5	1
20	1	.	.	.	3	3	2	.	.
21	1	.	.	.	3	3	2	.	.
22	.	.	.	.	3	.	.	3	.
23	2	.	.	.	1	.	1	.	.
24	6	.	.	.	1	3	.	.	.
25	2	.	.	.	2	1*	.	.	.
26	3	.	.	.	1	.	.	.	2
27	3	.	.	.	1*	.	.	.	4
30	2	.	.	.	3	.	.	.	.
31	.	.	.	.	x*	.	.	.	.

(The star indicates that the crystal was doubly terminated, but the faces on one end only are given.)

The forms may be characterized as follows:

Prisms.

The prisms usually show a triangular cross-section with rounded corners, but sometimes the cross-section is nearly circular. This is due in part to the development of three or four prisms, partly or completely, and in part to the oscillatory combination of these prisms. The prism zone is badly striated in its length from this cause and in measurement yields signals every few degrees.

b, $(10\bar{1}0)$. Twenty-four out of the twenty-eight crystals which were measured systematically showed faces of the first order prisms, and eleven of these showed all its faces. It is easily the dominant form on the mineral, and it is the least striated of any prism. In most cases it was developed trigonally.

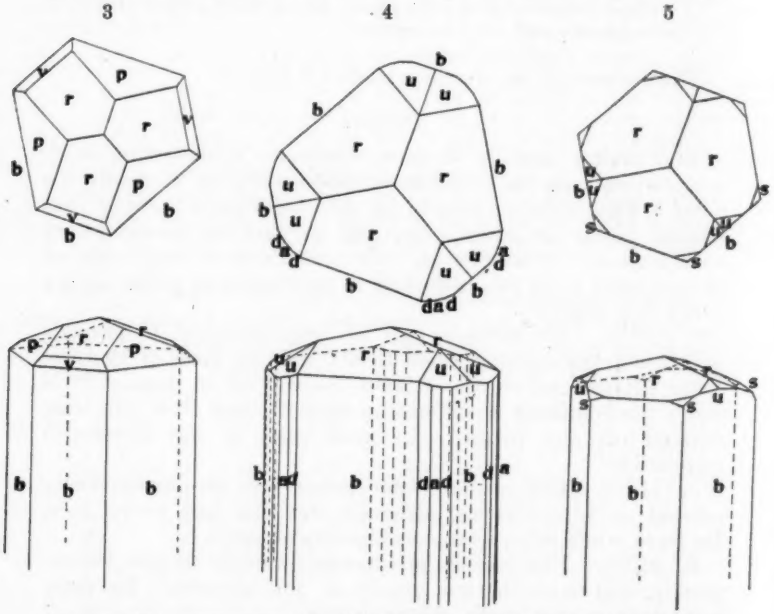
a, $(11\bar{2}0)$. The second order prism was also undoubtedly present on nine crystals, although but one had every face. Its faces when large were considerably striated.

k, $(21\bar{3}0)$. This known prism was found developed incompletely, but none the less surely on four crystals. Its faces were narrow and poorly characterized.

d, $(72\bar{9}0)$. This new prism was found developed incompletely on seven crystals, and the data establishing it are given in full in the following table:

Crystal.	Signal.	Reading. ϕ	
1	very poor	16° 48′	
2	very poor	17° 30′	
2	very poor	17° 33′	
3	poor	17° 58′	
3	poor	17° 59′	
4	good	17° 47′	
4	very good	17° 51′	
9	fair	17° 11′	
9	good	17° 42′	
9	poor	18° 25′	
9	fair	18° 26′	
12	very poor	17° 45′	
19	fair	16° 48′	
Average	fair to poor	17° 47′	average.
Calculated		17° 47′	

The calculated value of ϕ for this form is curiously in exact agreement with the mean of the measurements. So, although



this precise agreement is of course mere chance, it is near enough to establish the form and there are faces enough, well distributed among the crystals, to confirm it. Its faces are narrow and quite indistinguishable from the oscillation planes with which it is associated.

Rhombohedrons.

These are the chief terminating faces whether they occur as cleavage or as crystal planes. The faces, when crystal planes, are not very bright, although the markings and roughnesses which make them dull are never well characterized.

r, $(10\bar{1}1)$. The unit rhombohedron was found on all but two of the measured crystals. In a very few instances it was certainly cleavage; and in a few cases it was impossible to say whether cleavage or natural growth had produced the facet. It was developed in relatively large and perfect facets, constituting the dominant terminating form. While not always of good reflecting quality, the faces were usually definite and exhibited no definite markings.

p, $(02\bar{2}1)$. Next to *r* the new rhombohedron *p* is best developed as a termination. It is not found as cleavage. It occurs in rather large faces of dull reflecting power for the most part. It is missing from nine crystals only out of the twenty-eight measured, occurring, therefore, with less frequency than *r*. No definite markings were seen on its faces. The observations on which it is based are stated in summary form on p. 349.

v, $(50\bar{5}2)$. This rhombohedron, noted by Miller in his first paper, but omitted from his Mineralogy, occurs on five of the crystals, three of them, singly terminated, showing two faces each. The measurements on which the form is based follow.

Crystal.	Signal.	Readings.		
		ϕ	ϕ_1*	ρ
16	good	$\bar{2}9°\ 39'$	29° 39′	44° 03′
16	good	$\bar{1}49°\ 41'$	29° 41′	43° 57′
18	very good	$\bar{1}49°\ 19'$	29° 19′	43° 23′
20	poor	$\bar{3}0°\ 42'$	30° 42′	43° 33′
20	good	$\bar{1}50°\ 07'$	30° 07′	43° 25′
21	fair	$\bar{2}9°\ 52'$	29° 52′	43° 24′
21	good	$\bar{1}50°\ 10'$	30° 10′	43° 25′
24	fair	89° 31′	29° 31′	43° 51′
Average	very good to fair		29° 53′	43° 39′
Calculated			30° 00′	43° 23′·

Scalenohedrons.

These forms are entirely new to millerite. They are present on the Orford mineral as small but distinct facets on over half the crystals measured. The faces are fairly bright, yielding good images, and for the most part they are not pitted or striated.

s, $(21\bar{3}1)$. This scalenohedron occurs on two singly terminated crystals, in one case five of its faces being present. The measurements which establish it are given below.

* ϕ_1 is the value of ϕ referred to the first sextant on the right, that is, the difference between ϕ and the nearest multiple of 60°.

Crystal.	Signal.	Readings. ϕ	ϕ_1	ρ
19	fair	$\bar{1}1°\ 13'$	$11°\ 13'$	$44°\ 59'$
19	very poor	$\bar{4}9°\ 03'$	$10°\ 57'$	$44°\ 59'$
19	good	$\bar{1}30°\ 55'$	$10°\ 55'$	$45°\ 01'$
19	good	$\bar{1}69°\ 06'$	$10°\ 54'$	$45°\ 01'$
19	very poor	$109°\ 10'$	$10°\ 50'$	$45°\ 01'$
22	fair	$\bar{4}9°\ 24'$	$10°\ 36'$	$44°\ 55'$
22	fair	$\bar{1}31°\ 16'$	$11°\ 16'$	$45°\ 00'$
22	poor	$\bar{1}69°\ 29'$	$10°\ 31'$	$45°\ 00'$
	Mean of 8		$10°\ 54'$	$44°\ 59'·5$
	Calculated		$10°\ 53'·$	$45°\ 00'·$

The form is seen to be well established by these results.

u, $(\bar{4}\bar{1}53)$. This scalenohedron occurs on ten crystals, in two cases all its faces being present. The faces, however, are not very bright. They are rough and pitted for the most part and the images are only fair. The data follow.

This scalenohedron and the uncertain ones, *n*, *o*, *q* and *w*, lie in the zone with the rhombohedrons *r* and *p*, and their faces generally appear as striations or roundings of the edges between *r* and *p*, or as shown in figure 4, without *p*.

Crystal.	Signal.	Readings. ϕ	ϕ_1	ρ
2	extremely poor	$20°\ 02'$	$20°\ 02'$	$30°\ 07'$
2	fair	$40°\ 23'$	$19°\ 37'$	$30°\ 33'$
2	good	$139°\ 21'$	$19°\ 21'$	$30°\ 03'$
2	good	$160°\ 57'$	$19°\ 03'$	$30°\ 01'$
2	extremely poor	$\bar{1}01°\ 08'$	$18°\ 52'$	$30°\ 01'$
2	very poor	$\bar{7}8°\ 14'$	$18°\ 14'$	$30°\ 01'$
4	very poor	$40°\ 33'$	$19°\ 27'$	$30°\ 11'$
4	extremely poor	$139°\ 42'$	$19°\ 42'$	$30°\ 11'$
4	extremely poor	$160°\ 26'$	$19°\ 34'$	$30°\ 11'$
4	extremely poor	$\bar{1}00°\ 00'$	$20°\ 00'$	$30°\ 11'$
4	extremely poor	$\bar{8}0°\ 05'$	$20°\ 05'$	$30°\ 11'$
4	extremely poor	$20°\ 37'$	$20°\ 37'$	$30°\ 11'$
5	very poor	$141°\ 36'$	$21°\ 36'$	$30°\ 40'$
7	extremely poor	$138°\ 41'$	$18°\ 41'$	$30°\ 40'$
7	extremely poor	$161°\ 25'$	$18°\ 35'$	$30°\ 40'$
7	extremely poor	$\bar{7}9°\ 32'$	$19°\ 32'$	$30°\ 40'$
9	poor	$\bar{9}9°\ 52'$	$20°\ 08'$	$30°\ 42'$
19	very poor	$159°\ 51'$	$20°\ 09'$	$30°\ 45'$
26	poor	$41°\ 20'$	$18°\ 40'$	$30°\ 00'$
26	very poor	$18°\ 51'$	$18°\ 51'$	$29°\ 49'$
27	poor	$41°\ 07'$	$18°\ 53'$	$29°\ 42'$
27	poor	$100°\ 12'$	$19°\ 48'$	$29°\ 42'$
27	very poor	$161°\ 48'$	$18°\ 12'$	$29°\ 42'$
27	very poor	$138°\ 38'$	$18°\ 38'$	$29°\ 42'$
	Mean of all (24)		$19°\ 24'·$	$30°\ 04'$
	Mean of best		$19°\ 05'$	$30°\ 07'$
	Calculated		$19°\ 06'$	$30°\ 00'·$

Doubtful Forms.

The following forms, for one reason or another, given in detail under each form, are presented as possibly present on the species, but not as established beyond cavil.

i, (41$\bar{5}$0). This form was reported by Laspeyres, but not very well established by his measurements. We obtained poor measurements partly confirming it, but the form is still in doubt, neither his measurements nor ours being good enough to certify it. Our measurements follow.

Crystal.	Signal.	Reading. ϕ
2	extremely poor	18° 52′
2	extremely poor	18° 58′
2	poor	19° 01′
Average	very poor	18° 57′
Calculated		19° 06′·4

The agreement of our measurements with the calculations is better than that of Laspeyres's measurements, but the faces noted were all on one crystal, and two of them were very doubtful.

f, (9·4·$\bar{13}$·0). This prism is new and the measurements on which it is based follow.

Crystal.	Signal.	Reading. ϕ
7	fair	12° 26′
12	poor	12° 29′
14	very good	12° 29′
Average	fair to good	12° 28′
Calculated		12° 31′·2.

The agreement is close enough to establish the form, but the faces are few in number, though well distributed. The signals, however, are good, and in the case of crystal 14, at least, the reading corresponds to a definite face of good quality which can be seen in the goniometer. In this respect the face differs from most of the oscillation planes and, moreover, it is placed very close to its computed position. Therefore the form is regarded as probable, but confirmation is necessary.

g, (31·13·$\bar{44}$·0). This prism, so far as our measurements go, is better established than the form *i*, and so is given, but it has complex indices and altogether is a doubtful form.

Crystal.	Signal.	Readings. ϕ
2	extremely poor	13° 11′
8	extremely poor	13° 22′
14	good	13° 19′
Average	poor	13° 17′·3.
Calculated		13° 17′

Besides the signals reflected from faces of these forms which are more or less well established, there were read, in the prism zone, signals reflected from faces in thirty-two positions (reduced to the positive sextant) which corresponded more or less well to prisms of complex indices. For the most part only one face of each of these forms was seen, and the signals were generally of very poor quality. These facts together with the complexity of the indices deduced, and the certainty of the occurrence of oscillation-vicinals whose signals correspond to no prism however complex, render the establishment of any of them very doubtful. Therefore all are rejected and none of the data is published.

Doubtful Rhombohedrons.

t, (03$\bar{3}$1). This rhombohedron was reported by Miller on the strength of a contact measurement on a rough terminated crystal. We can not confirm the form, but one face on one crystal was found approximating to its position.

Crystal.	Signal.	Readings. ϕ	ρ
24	very poor	30° 00′	48° 56′
Calculated		30° 00′	48° 36′

h, (30$\bar{3}$1). This rhombohedron is new and very doubtful, relying for its establishment on two measurements on two different crystals.

Crystal.	Signal.	Readings. ϕ	ρ
23	very poor	30° 00′	48° 42′
24	fair	150° 00′	48° 10′
Mean	poor	30° 00′	48° 26′
Calculated		30°	48° 36′

The form is therefore certainly indicated, but by no means established.

x, (40$\bar{4}$1). This form also is new and rests on a single measurement whose signal was of fair quality. The measured value for ρ was 56° 34′; the calculated value of ρ is = 56° 31′49″; apparently the form only lacks the finding of more faces to establish it.

j, (50$\bar{5}$1). One face only supports this form.

Crystal.	Signal.	Readings. ϕ	ρ
23	poor	29° 46′	62° 26′
Calculated		30° 00′	62° 07′

l, (09$\bar{9}$1). Only one face of this form was found. This gave a fair signal showing a definite face.

Crystal.	Signal.	Readings. ϕ	ρ
25	fair	29° 25′	73° 05′
Calculated		30° 00′	73° 37′

m, (0·18·$\bar{1}$8·1). Only one face of this form was found which yielded two signals of fair quality.

Crystal.	Signal.	Readings. ϕ	ρ
24	fair	30° 00′	82° 32′
24		30° 00′	80° 20′
Calculated		30° 00′	81° 38′

No stress is laid on the probability of the occurrence of *l* and *m*. The faces were plainly visible in both cases.

Doubtful Scalenohedrons.

n, (52$\bar{7}$6). This form was found on three crystals, in one case four of its faces being present. The data follow:

Crystal.	Signal.	Readings. ϕ	ϕ_1	ρ
5	good	104° 52′	15° 08′	21° 18′
5	poor	133° 21′	13° 21′	21° 18′
8	poor	$\bar{1}$33° 14′	13° 14′	21° 22′
8		$\bar{4}$6° 39′	13° 21′	21° 22′
8		73° 01′	13° 01′	21° 22′
8	very poor	$\bar{1}$66° 45′	13° 15′	21° 22′
14	poor	$\bar{1}$67° 14′	12° 46′	21° 26′
Mean	poor	-------	13° 26′·5	21° 21′
Calculated		-------	13° 54′	21° 29′

Although we have left the form in doubt it is clear that it is more than indicated. The agreement of measurements with calculations is only fair, but there are many faces well distributed.

o, (7 · 4 · $\bar{1}\bar{1}$ · 9). This form was found on three crystals, in one case four faces being present. The data are given in full:

Crystal.	Signal.	Readings. ϕ	ϕ_1	ρ
5	poor	$\bar{8}$° 52′	8° 52′	22° 03′
5	very poor	$\bar{5}$0° 58′	9° 02′	22° 00′
8	extremely poor	$\bar{7}$° 30′	7° 30′	21° 22′
18	poor	$\bar{9}$° 51′	9° 51′	21° 19′
18	extremely poor	$\bar{1}$71° 40′	8° 20′	21° 51′
18		$\bar{1}$28° 24′	8° 24′	21° 36′
18	poor	$\bar{4}$9° 46′	10° 14′	21° 09′
Mean	very poor	-------	8° 53′	21° 37′
Calculated		-------	8° 57′	22° 03′

This form, therefore, is not to be rejected without consideration although the data cannot be said to establish it.

q, ($\bar{6}1\bar{7}4$). This form rests on two readings made on a single crystal. This crystal was the richest in forms of any measured. The agreement is not very bad. The form is at least indicated.

Crystal.	Signal.	Readings. ϕ	ϕ_1	ρ
2	poor	$\bar{8}3°\ 05'$	$23°\ 05'$	$32°\ 00'$
2	very poor	$\bar{9}7°\ 33'$	$22°\ 27'$	$32°\ 00'$
Mean	poor	-------	$22°\ 46'$	$32°\ 00'$
Calculated		-------	$22°\ 24'$	$31°\ 47'$

w, ($42\bar{6}5$). Only one reading supports this form. It in consequence is very doubtful.

Crystal.	Signal.	Readings. ϕ	ϕ_1	ρ
5	fair	$70°\ 26'$	$10°\ 26'$	$21°\ 47'$
Calculated		-------	$10°\ 53'$	$21°\ 48'$

Résume.

The Orford millerite has yielded a number of terminated, measureable crystals from which the new axial ratio $a : c = 1 : 0{\cdot}2183$ is calculated. In addition to the forms previously known, one new prism, two rhombohedrons and two scalenohedrons are definitely established and a number of uncertain forms observed but not established.

The presence of a gliding plane parallel to the negative rhombohedron, along which pressure twins of great perfection can be easily obtained, is also determined.

Millerite has been thought to be hemimorphic like the nearly related cadmium sulphide, greenockite, and has been so classified by Groth. The sharply defined trigonal character of many of the prisms of Orford millerite seem to give some basis for this assumption; and doubly terminated crystals were therefore eagerly sought for in the hope that the question might be settled by definite observations. A few crystals doubly terminated were found but they were poor crystals and so far as measurements could be made upon them showed no unlikeness between the two ends. Our evidence on this matter is therefore not conclusive.

On the surface of a single hand specimen of very rich green chrome garnet which was originally covered with a thin layer of calcite, there appeared on the removal of the latter with acid a number of tiny clusters of crystals of a gray to white metallic mineral which seem to be rammelsbergite, an arsenide of nickel. The crystals are minute and invariably so deeply striated that no satisfactory measurements could be obtained. Still inasmuch as this mineral has never been found before in crystals that permitted of measurement except in one zone, a number of the crystals were studied carefully and a provisional axial ratio was calculated for the species. It was found to be like the other

members of the marcasite group in habit and the flat dome which was found on all measured crystals was taken by analogy with arsenopyrite as the brachydome (014). The prism zone was so deeply striated that no reliance could be placed on the readings made from it; but an orthodome was found on nearly all the crystals very faintly developed but which gave fairly uniform readings for ρ. This was taken as (102), a choice that gave the simplest indices for the prism forms and a ratio most nearly like that of the other members of the group, although differing widely from any of them. The observations follow:

Rammelsbergite?.

$0\frac{1}{2}$ av. of 7, $\phi = 0° 00'$, $\rho = 16° 06'$ $\}$ $p_o = 2{\cdot}0176$
$\frac{1}{2}0$ av. of 4, $\phi = 90° 00'$, $\rho = 45° 15'$ $\}$ $q_o = 1{\cdot}1545$

$$a : b : c = 0{\cdot}57222 : 1 : 1{\cdot}1545$$

Form.		Calculated.		Measured.		No. of observations.
G.	Miller	ϕ	ρ	ϕ	ρ	
$0\,\infty$	010	00° 00′	90° 00′	00° 00′	90° 00′	6
∞	110	60° 13′	90° 00′	60° 44′	90° 00′	3
$\infty\,2$	120	74° 02′	90° 00′	74° 26′	90° 00′	4
$2\,\infty$	210	41° 09′	90° 00′	42° 30′	90° 00′	2
$0\frac{1}{4}$	014	00° 00′	16° 06′	00° 00′	16° 06′	7
$0\frac{1}{3}$	013	00° 00′	21° 03′	00° 00′	20° 30′	2
$0\frac{1}{2}$	012	00° 00′	29° 59′	00° 00′	29° 45′	1
02	021	00° 00′	66° 35′	00° 00′	66° 50′	1
$\frac{1}{2}0$	102	90° 00′	45° 15′	90° 00′	45° 15′	4

The amount of the mineral present on our specimens was so small that sufficient for analysis could not be secured. Its doubtful determination as rammelsbergite is based on blowpipe reactions for arsenic and nickel obtained on minute crystals. No test for sulphur could be obtained. It is hoped that more and better material may ultimately be obtained which will enable the character of this mineral to be definitely established.

EXPLANATION OF THE FIGURES.

Fig. 1 shows a photograph of a specimen from which calcite has been partly removed by solution in hydrochloric acid. Several large straight prisms of the millerite may be seen still partly embedded in the calcite. On the surface of the pyroxene matrix may be seen several smaller broken and twisted millerite crystals.

Fig. 2 shows a twin crystal produced by pressure, twinned parallel to the rhombohedron e, $(01\bar{1}2)$. The upper termination is formed by single planes of the two cleavages, parallel to r and e; the lower termination is by a single plane of the r cleavage.

Fig. 3 shows in plan and perspective the commonest type of crystal found. The proportions of the rhombohedrons may vary but some or all of the faces of the three are generally found.

Fig. 4 and Fig. 5 show the mode in which the scalenohedrons occur in combination. Of these forms u is much the more frequent, s having been observed on but two crystals.

Harvard Mineralogical Laboratory,
June 1904.

Art. XXXVIII.—*Unconformity of the Cretaceous on Older Rocks in Central New Mexico;* by Charles R. Keyes.

In New Mexico Cretaceous sedimentation is enormously developed. The total thickness of the strata referable to this age cannot be less than 7000 feet.

In eastern New Mexico and Texas the sequence of the Cretaceous formations is quite complete. Both the Lower Cretaceous and the Upper Cretaceous are well represented. Below are the "Red Beds," probably composed partly of Triassic sandstones and shales and partly of Carboniferous layers of similar lithologic characters. These attain a thickness of 2000 feet and upwards. Then below all these are the great Carboniferous limestones, which are about 2000 feet thick and which form the backslopes of most of the block mountains of the Basin region. The generalized geological section for New Mexico may be tabulated as follows:

Ages.	Systems.	Thickness.	Formations.	Rocks.
Cenozoic	Quaternary	200		Gravels
	Tertiary	200	Galisteo	Sandstones
		800	Puerco	Clays
Mesozoic	Cretaceous	2000	Laramie	Sandstones
		1500	Montana	Shales
		800	Colorado	Shales
		400	Dakota	Sandstones
		800	Comanche	Sandstones
	Triassic	1000	Cimarron	Shales
Paleozoic	Carboniferous	1000	Bernalillo	Shales
		300	Madera	Limestones
		300	Sandia	Limestones
		200	Lake Valley	Limestones
	Devonian	200	Chloride	Limestones
	Ordovician	400	Pinos Altos	Limestones
	Cambrian	300	Tonto	Sandstones
Azoic	Algonkian	300	Chuar	Shales
		1000	Grand Canyon	Sandstones
		500	Vishnu	Quartzites
	Archean	2000		Schists

The relationships of the Cretaceous system to the other formations, as displayed in central New Mexico, have long been a puzzle. Throughout the region the Red Beds constitute a conspicuous and important formation. Owing, how-

ever, to the peculiar position they occupy when well exposed on the lower backslopes of the block mountains, with the Cretaceous coming in immediately, the exact disposition of the two great formations is seldom clearly discernible. Then, too, at the bases of mountains vast plains stretch away, which are deeply covered by gravels, sands and clays washed down from the higher elevations, and which cover effectually all traces of the indurated rocks beneath. While these underlying rocks usually are more or less highly inclined, they have been completely bevelled off to a surface that is as even and level as the plains themselves.

That the Cretaceous rocks in central New Mexico rest unconformably on the older formations has been for some time surmised. The difficulty has been to obtain indisputable evidence in support of this hypothesis. This proof has lately been secured; and the facts are of exceptional interest.

1

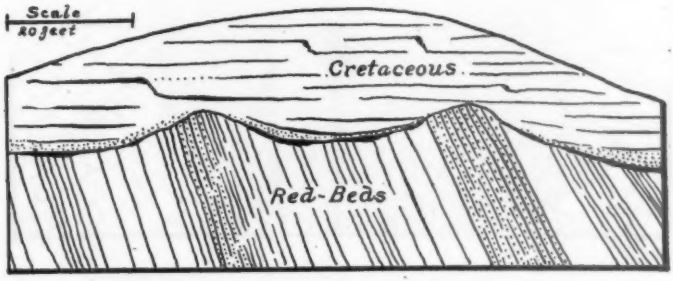


FIG. 1. Cretaceous and Red Beds at Tejon, New Mexico.

In a number of instances the Cretaceous sandstones have been found to repose apparently in perfect conformity upon the Carboniferous limestones. There is no evidence whatever of the existence of the great thickness of Red Beds between sandstone and limestone. If the Red Beds ever existed there they were swept cleanly away from the surface of the limerock. But the bedding planes of the Carboniferous and Cretaceous formations were to all appearances parallel.

East of the Sandia Mountains the Cretaceous deposits extend almost uninterruptedly to the Texas line. At the north end of the range where the backslope of Carboniferous limestone begins to sink under the plains, a small stream has cut deeply through the Cretaceous sandstones into the Red Beds beneath. At this place the Red Beds are standing on end, while the yellow Cretaceous beds are lying very nearly horizontally. The relationships are best indicated by diagram (figure 1).

A still more instructive section is displayed in the canyons cutting the Chupadera Mesa, 50 miles east of Socorro. The surface rock of the great mesa is horizontally disposed Cretaceous sandstone, rather massively bedded and yellowish in color. The dissecting canyons are 300 to 400 feet deep. They disclose the blue Carboniferous limestones in many places. A number of enormous dikes of gray trachyte traverse the district where the limestones are displayed. Along these dikes are large deposits of iron ore. On either side of the dike the limestone is abruptly upturned, often nearly to a vertical attitude. The cross-section is shown in the subjoined cut (figure 2).

2

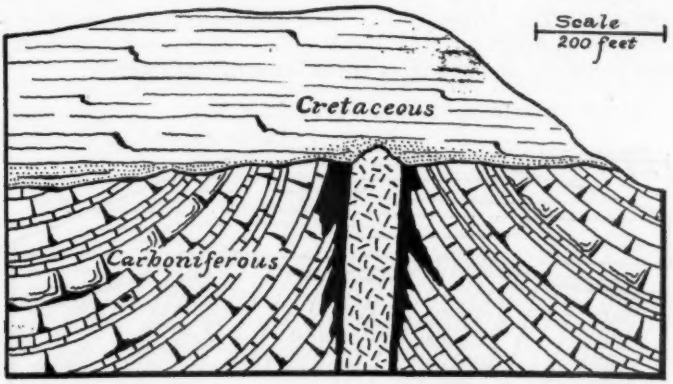


FIG. 2. Unconformity of Cretaceous on Carboniferous.

At this particular point the Cretaceous beds repose horizontally, while in a distance of a thousand feet the Carboniferous limestones change in dip from horizontal to vertical. The dike is 200 feet thick. The iron ore on either side is of varying thickness, and fills the jagged edges of the broken limestone.

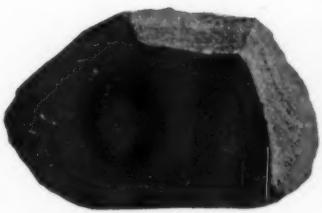
With the recognition of an enormous erosion interval in central New Mexico prior to the deposition of the Cretaceous sandstones, the working out of the geology of the region is greatly simplified. Many hitherto inexplicable phenomena now find easy solution. The Cretaceous of the region is all Upper Cretaceous. Nowhere have the Lower Cretaceous beds been found.

The duration of the erosion interval was thus probably equivalent to the sedimentation period of the entire Lower Cretaceous of the Texas area.

New Mexico School of Mines, Socorro, August 30, 1904.

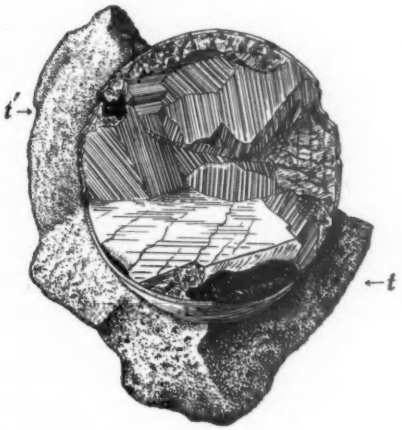
1

2

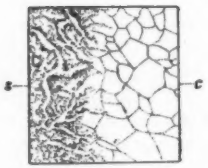


3

4

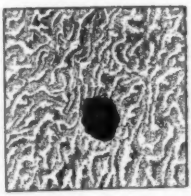


1

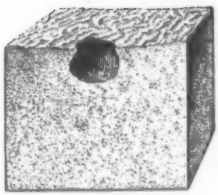


2a

2b



3



4

ART. XXXIX.—*A Peculiar Occurrence of Bitumen and Evidence as to its Origin;* by WM. CONGER MORGAN and MARION CLOVER TALLMON. (With Plates XVIII and XIX.)

Summary.

THE following is a description and an account of the examination of a fossil egg from Arizona. When discovered it was enclosed in a limestone matrix which has kept the specimen in a very fine state of preservation. Crystallized colemanite and a tarry material resembling natural asphalts are found within the eggshell. All the evidence which can be collected from the specimen indicates that the asphalt-like substance is part of the original contents of the egg which has become bitumized.

Introduction.

Very few instances of the occurrence of eggs in the fossil state have been recorded. The fossil eggs of New Zealand birds are only shells which have been preserved by reason of their thickness and strength. The Chelonian eggs of Tertiary age from Auvergne, France, are simply shells filled with hardened mud. An interesting fossil egg from the American Miocene has been described by Mr. Oliver C. Farrington,* and has been considered the egg of a duck.

The specimen described in this paper was brought to the attention of Professor John C. Merriam some months ago by Mr. G. A. Helmore of San Francisco. It had been in Mr. Helmore's possession for some years, and was obtained by him from a prospector who found it in a large pebble embedded in placer gravels on the Gila River in Arizona. Mr. Helmore, being unwilling to part with the specimen, has kindly loaned it to the University of California for study and description. To Professor Merriam the authors wish to acknowledge their indebtedness for valuable suggestions during the course of the work.

Occurrence.

Unfortunately, the information which we have concerning the occurrence of this specimen does not give us very definite evidence concerning its age. The encapsuled egg is said to have been a pebble in gravels some distance above the present level of the river. If, as has been supposed, the gravels are bench deposits, the egg is at least as old as the Quaternary. If they are of recent origin, we can still hardly suppose it younger than Quaternary, as it is only under the most extraordinary circumstance that deposits of recent origin can occur as hard pebbles in recent conglomerates.

* Field Columbian Museum, Pub. 35, vol. i, No. 5, Geological Series. A Fossil Egg from South Dakota.

Description.

The egg as found forms the center of a rounded mass of hard calcareous rock, which may be called the capsule or matrix. Its appearance is that of an ordinary irregularly-shaped river pebble, about $3\frac{1}{2} \times 4 \times 5$ inches in dimensions. It is well worn by the action of water, and shows striations in a plane parallel with the longer diameters, apparently due to differential weathering of the thin layers of the matrix. By a blow of a pick a piece was broken out of one side of the pebble, revealing a smooth inner core, from the appearance of which the finder had no hesitation in pronouncing it a fossil egg embedded in rock. When the specimen came into our possession, part of the surrounding matrix had been removed and the egg broken open. (Pl. XVIII, figs. 2 and 4.)

In order to expose fresh surfaces for observation the matrix was completely removed. It separated readily and exposed what appears externally to be a typical egg in all respects. (Pl. XVIII, fig. 1.) It is oval in shape, but little removed from an ellipsoid, however, and measures 62×40^{mm} ($2{\cdot}44 \times 1{\cdot}57$ inches). Its shape indicates very clearly that it belongs to the class of water-birds, and by comparison with the eggs of birds of the present time, it is found to correspond closely with the type of egg laid by the cormorant. The character of the shell is entirely unlike these rough chalk-coated eggs, however, but shows a finely pitted surface with some degree of polish such as is found in eggs of the duck family. The minutest markings of the shell are preserved in the matrix, moreover, and in this there is no evidence of any scratches such as usually occur in the chalky layer of cormorant's eggs. It is true that the shell proper lying underneath the outer chalky layer of a cormorant's egg shows a pitted surface much like that of the present fossil specimen. It seems improbable, however, that the chalky layer could have been washed off without injury being done to the egg, neither is it probable that it was firmly united with the matrix and pulled away in separating the egg-shell from the rock.

While the specimen most resembles in shape the type egg of the cormorant, it is also much like the egg of the larger grebes or herons, the American bittern or limpkin. Again, while the ratio of the short to the long diameter is somewhat less than that of the typical egg of the duck, its dimensions correspond almost exactly with measured eggs of many of the larger species of this family, thus showing that its divergence from the type is not greater than could be accounted for by individual variation.

In microscopic structure the same similarity is apparent. Under the lens the shell of a wild goose or of a duck's egg is

practically indistinguishable from the fossil shell, which shows distinctly the two characteristic layers, the outer one veined, the inner one prismatic. (Pl. XIX, figs. 2*a* and 2*b*.) The shell is light buff in tint, but any inference from its present to its original color would hardly be significant. It is probable that when this egg was deposited the region was not near to the sea. Under geographic conditions similar to those now obtaining, ducks would be more numerous than any of the other possible forms, and the probabilities, therefore, favor anatine origin of the egg.

Since it was not desirable to mutilate the specimen unnecessarily a quantitative analysis of the shell was not possible. Qualitative analyses of the shell of the fossil egg and the shell of a wild-goose's egg were made in parallel, on approximately equal amounts of material in equal volumes of solution with the same number of drops of the different reagents. With the exception of organic matter the fossil gave tests for every element found in the egg of the goose apparently to the same degree, the only difference noticeable being that the fossil contained a trifle more iron.

Taking into consideration the facts that the fossil eggshell is in chemical composition similar to, and in physical structure practically indistinguishable from, the shells of birds' eggs of the present time, the hypothesis that the material of the fossil eggshell as it exists to-day is the same as was present originally seems unquestionable. Moreover, the minute tracings of the shell are reproduced on the inner surface of the surrounding capsule. This fact makes it necessary to assume that the egg was encased very soon after it was deposited in the nest, and that subsequently it has been subjected to no conditions likely to modify its microscopic structure.

Contents.

By far the larger portion of the contents of the egg consists of beautifully crystalline colorless colemanite, showing the characteristic plates, striations, cleavage, hardness, extinctions and other physical properties. (Pl. XIX, fig. 1.) An analysis gives the following composition:

	Calculated.	Found.
CaO	27·21 per cent	27·07 per cent
B_2O_3	50·93 "	51·00 "
H_2O	21·85 "	22·01 "

While the colemanite in many places comes in direct contact with the shell of the egg, in other places it is separated from

it by a tarry material which, wherever it occurs, is invariably in contact with the shell. The main deposit of this tar is assumed to be on the lower side of the egg as it lay buried. (Pl. XIX, fig. 1, *t*.) The contacts between this deposit and the colemanite above it are smooth, gently rounding surfaces, without inclusions of either substance in the other. The second largest deposit of tar is almost diametrically opposite the one just mentioned, on what seems to have been the upper side of the eggshell. While the character of the tar is identical, the nature of the contact is entirely different. A little mass of tar of irregular shape is almost completely surrounded by the colemanite and hangs down from above like a pendant. (Pl. XIX, fig. 1, *t'*.) Other slight deposits of tar in various parts of the egg present only similar phenomena. No inclusions of the colemanite in the tar could be anywhere detected.

The surfaces bounding the cavity in the colemanite in which the tar is included are smooth and roughly spherical. Had the colemanite crystallized freely, we should expect the bounding surfaces to be right-lined and planar, conforming to the faces of the crystals, and not spherical as in the present instance. The shape of any deposit of material subsequently laid down must of necessity correspond to those surfaces on which it is deposited. Considering the inclusion of the tar in the mineral, the shape of the included mass and the nature of the contacts, there seems to be no doubt that the entrance of the colemanite took place after the tar had already accumulated inside the shell. Hence it was that the colemanite crystallized about the tar, the nature of the surfaces of contacts being determined by the tar and not by the crystallizing mineral.

Besides the deposits of tar inside the shell, there is a thin film of the same material between the shell and the matrix, adhering to both. On the inner surface of the matrix, a number of small black prominences are plainly in evidence (Pl. XIX, fig. 3), which, under the lens, seem to be minute deposits of the same tarry material. They readily disappear when the rock is washed off with chloroform, and, after thorough extraction, in place of the prominences little globular cavities or sacks are found. (Pl. XIX, figs. 3 and 4.) The diameters of these openings increase after penetrating beneath the surface of the matrix. Microscopically examined, the limestone about these cavities appears identical in character with that removed from their vicinity. The cavities are found to correspond with visible canals in the eggshell. The number of pits in a given piece of matrix corresponds with the number of visible passages in that part of the shell from which the matrix was removed, the relative distribution of each being about the same. A minute crack in the shell is also filled with tar and

a corresponding tarry ridge is noticeable in the matrix. Since the homogeneity of the matrix offers no evidence to indicate that the little cavities are the remains of passages to the exterior, subsequently filled with more recently deposited material, and since the juxtaposition of cavity in the matrix and canal in the eggshell offers evidence that the cavities were formed from within, there seems to be no reasonable hypothesis other than that the tar at present outside the shell and in the immediate layers of the matrix came from within and was forced outward from the center.

To offer a reasonable explanation of the formation of these pits is not an easy matter. Since they are intimately connected with the canals through the eggshell, and these canals as well as the pits are filled full with tar, it would seem as though some corroding action of the tar might be connected with their formation. Not the slightest acid reaction can be obtained from the tar in any way with litmus or phenolphthalein, however; hence the solution of the limestone would hardly seem to be due directly to the tar.

The ready solubility of calcium carbonate in water containing carbon dioxide naturally suggests itself. However, the formation of carbon dioxide or of organic acids from the original decomposition of the egg can hardly be supposed to have caused the action. It is questionable whether a limestone matrix could form about an egg before its contents had broken down to relatively very stable decomposition products. Moreover, if these pits had been present in the matrix when the colemanite came in, they would in all probability have been filled with this mineral. It is necessary to assume either that these pits did not exist when the colemanite came in, or that they were already filled with tar which prevented the mineral from filling them. Since the tar that fills them unquestionably came from inside the shell, the only force considered sufficient to make a viscous tar leave a large cavity to fill a small pit would be due to the crystallizing colemanite. As the crystals formed, the resulting pressure forced the tar through the larger canals in the eggshell. Through the fine-grained matrix it could not go because of its viscosity.

The fact that the tar filling these pits has an earthy appearance, like that produced in the "weathering" of asphalts, may offer a clue as to the formation of the pits. Oxygen dissolved in the waters percolating through the strata in which this specimen was embedded, might account for a local oxidation of the tar as it emerged from the pores of the eggshell, the carbon dioxide formed producing an initial solution of the material of the capsule. As soon as the matrix was appreciably dissolved, the tar was forced into the new-formed

cavity and the action began again. Since the oxidation would take place over the whole surface of the minute drop exuding from the pore in the shell, the cavity formed would naturally assume the spherical shape which these pits possess.

The Bituminous Material.

The tar is a semifluid substance of very dark brown color, resembling natural asphalts in appearance and physical properties. At 10° C. it is brittle, showing a conchoidal fracture with brilliant surfaces, the edges of the fracture becoming rounded on standing. As the temperature rises it grows softer, until at 100° C. it becomes a fluid with considerable viscosity. Its specific gravity is a trifle less than that of boiling water. It is readily and completely soluble in petroleum ether, turpentine, carbon disulphide and chloroform; much less in acetone and ether, and only very slightly soluble in alcohol even when boiling. No residue of an organic or inorganic nature is left by any of these solvents. In all of these points it resembles the "petroleum-ether-soluble" fraction of all natural asphalts, long known as "petrolene."

In cold fuming nitric acid it is soluble, separating partially a jelly-like mass which resembles silicic acid. If the solution be now poured into water a flocculent precipitate separates, resembling aluminum hydroxide colored slightly with ferric hydroxide. This precipitate is soluble in fuming nitric acid.

If the solution of tar in nitric acid be heated, the jelly-like substance dissolves, and is not completely oxidized by evaporating to dryness. On boiling the residue with dilute nitric acid everything dissolves as the acid concentrates, and when poured into water now gives a flocculent red precipitate like ferric hydroxide, to which reference is made by Day,* in his investigation of gilsonite. This ferric-hydrate-like precipitate, on being heated with water, collects as a thick reddish oil, very slightly soluble in petroleum ether, but readily soluble in alcohol, especially when warmed, thus showing it to be a different body from the original tar.

Concentrated sulphuric acid dissolves the tarry material also, giving a dark red-brown solution which, on treatment with water, gives a precipitate similar to that from fuming nitric acid just described.

By the sodium nitroprusside reaction the tar gives qualitative tests for the presence of sulphur. A comparison of the intensity of color given by tests made on the tar with similar solutions containing known amounts of sodium sulphide would indicate about 0·2 per cent of sulphur in the tar. How much of the total amount present in the tar would escape conversion into

* Jour. Franklin Institute, cxl, p. 239 (1895).

alkaline sulphide by heating with metallic sodium is a matter of conjecture only, but it is probable that less than 1 per cent of the tar is sulphur.

Tests for nitrogen, by heating with sodium and precipitating the cyanide as Prussian blue, failed to indicate the presence of this element even when 0·3 gram of tar was treated. Under these circumstances the resulting solutions gave very strong tests for sulphur but not a particle of the blue precipitate could be obtained even on long standing.

In order to ascertain the delicacy of this method of detecting nitrogen in substances of a nature similar to those which might be expected to be present in the tar, qualitative experiments were made with known amounts of pyridine and quinoline. It was found that 0·01 gram of either substance would give a precipitate in such quantity that when diluted to 100^{ccm} and thoroughly mixed, 1^{ccm} would on settling give a distinct indication. Similar results were obtained by mixing the same amounts of pyridine with the tar and then heating with sodium. Certain natural asphalts known to contain nitrogen were tested by this method and gave positive results. Hence it is concluded that the failure to obtain evidence of nitrogen in the present instance was not due to the method. While heating the pyridine with sodium its odor was very apparent in the room, and since it is the most volatile member of this series of compounds it seems highly probable that if nitrogen were present in the tar to the extent of 0·05 per cent it would have been detected.

No evidence of phosphorus could be found, after oxidizing with fuming nitric acid and testing with molybdate solution.

None of the properties, either physical or chemical, which have thus far been set forth, indicate any difference between this tar and some pure natural asphalts.

A combustion of 0·1107 gram of the tar for carbon and hydrogen gave 0·2582 gram carbon dioxide and 0·1058 gram water, indicating 63·6 per cent carbon and 10·6 per cent water. These figures give 25·8 per cent oxygen and other elements, determined by difference. Since nitrogen is absent and sulphur present only in small amounts, oxygen seems to form about one-quarter of the entire substance.

These percentages do not agree even remotely with the figures given by asphalts, which show generally less than 5 per cent of oxygen. Incomplete combustion may possibly explain this discrepancy but there was no evidence of this during the progress of the combustion. Although a second determination was greatly desirable, the material for it was not at hand.

It is interesting to note in this connection, however, that certain bituminous substances have been reported as containing

a much greater percentage of oxygen than the figures in the present case. According to Schrötter* dopplerite contains 43·03 per cent oxygen. Elaterite appears to be associated sometimes with substances of high oxygen content, which makes the amount of oxygen present in the unpurified material run as high as 35 or 40 per cent.

On heating above 100° C. many natural asphalts and "breas" froth very characteristically because of the water contained in them. Inasmuch as no frothing occurs on heating this tar to 150° C. it is concluded that it contains no appreciable amount of water. This conclusion is supported by the fact that the petroleum ether, chloroform and carbon disulphide solutions are perfectly clear, showing not the slightest turbidity, a circumstance hardly probable if water were present chemically uncombined in the specimen.

As the temperature is raised above 100° C. the tar begins to decompose slowly. At 150° C. the action is very decided. A volume of inflammable gas, large in proportion to the weight of the substance heated, is liberated. This reaction is completed between 200° C. and 250° C. after which but little decomposition ensues until the temperature rises above that indicated on an ordinary thermometer.

An attempt was made to determine the boiling-point of the oily liquid left after such heating. It remained unchanged at 300° C., and, on heating the tube with a small flame, would creep away from the hotter portions without visibly boiling at 360° C.

The substance remaining after heating to 250° C., on cooling, resembles the original tar in appearance. It is, however, no longer completely soluble in petroleum ether. Only about two-thirds are dissolved by this solvent. Most of the remainder is soluble in carbon disulphide but there always remained a distinct residue which could only be dissolved in chloroform. In these solubility relations it resembles ordinary asphalt possessing a large "petroleum-ether-soluble fraction" ("petrolene") and a smaller "asphaltene" fraction soluble in carbon disulphide. The portion soluble only in chloroform is thought by Pecham† to be an indication of "weathering" in those asphalts in which it occurs in appreciable amounts. In this instance it is clearly formed by the action of heat. A combustion of 0·0405 gram of the material heated as described gave 0·1257 gram carbon dioxide and 0·0452 gram water, indicating 84·7 per cent carbon, 12·4 per cent hydrogen and about 3 per cent of oxygen and sulphur. These percentages correspond with the figures given by asphalts generally on combustion.

* Wien., Akad. Ber., 285 (1849).

† Jour. Franklin Institute, No. cli, pp. 114–124 (1901).

In short, this material can not be differentiated from ordinary natural asphalt in any way. It would appear that the tar as it exists in the fossil has not been completely bituminized, since it apparently contains considerably more oxygen than bituminous bodies generally possess. On heating to 150° C. the transformation is completed and the resulting product is in all respects a typical asphalt. The ready decomposition of the tar and the entire change in its composition and nature after being heated to 150° C. offer evidence that the specimen has never been heated to this temperature previously.

When the asphalt thus formed is heated to a dull red heat more gas is liberated, doubtless due to "cracking" of the high-boiling oils constituting it, and a residue resembling coke is left.

The Matrix.

The matrix in which the egg is embedded varies from a little less than half an inch to nearly an inch in thickness, and consists of a fine-grained gray limestone, readily effervescing when treated with dilute hydrochloric acid. A quantitative analysis was deemed unnecessary. Qualitatively examined, it gives slight tests for iron, aluminum, silicic and boric acids, the relative amounts being in the order named. Magnesium is present in larger quantity. No tests for sulphates, phosphates or chlorides were obtained. In short, the matrix seems to be a limestone of considerable purity. It shows no geological evidence of metamorphism whatever.

In an indentation in one side of the limestone is a small deposit of very fine hard clay, indicating that at some time during its history the fossil embedded in its limestone capsule has been buried under such conditions as to allow the formation of clay about it.

On being fractured, especially when crushed in a mortar, the limestone gives off the peculiar fetid odor supposed to be due to the presence of organic matter. On dissolving in hydrochloric acid an odor similar to that produced when iron and zinc are treated with acids becomes apparent, and a slight greasy scum is evident on the surface of the liquid when in a test-tube. The intensity of these phenomena is not greater than is observed frequently in limestones containing no appreciable amounts of organic matter.

In order to ascertain the nature and amounts of this organic matter present, a piece of the matrix weighing about 10 grams was extracted with petroleum ether to remove the tar filling the pits and covering the inner surface. The piece was then finely powdered and extracted again with boiling chloroform. Upon evaporation, from 9·7380 grams of the matrix 0·006 gram of tar similar to the other tarry material was obtained.

To ascertain whether this tar could be extracted from all sections of the matrix or was found alone in those layers nearest the center, pieces of the limestone from three different sections of the outer layers of the matrix, removed as far as possible from the fossil itself, were powdered and extracted similarly but no weighable residue was obtained from any portion. This indicates that the carbonaceous material soluble in chloroform is not distributed evenly throughout the matrix but is confined to the layers in the immediate neighborhood of the tar-filled fossil. Since the amount of tar extracted from the matrix previously mentioned represents only about 0·06 per cent of the weight of the limestone, inasmuch as the extracted material seems identical with the tar found inside the egg and covering the shell, it is believed that this amount was some of the same material from inside the shell which was not extracted by the solvent previous to grinding. Therefore it is believed that the matrix as a whole contains no carbonaceous matter of a bituminous nature.

To ascertain whether the matrix contains appreciable amounts of carbonaceous matter which will become bituminous on heating, about 10 grams of the limestone were heated in a hard glass tube in an atmosphere of carbon dioxide. The products of the ignition were passed through a freezing mixture to collect any liquid distillate and the gas was collected over potassium hydroxide solution. On heating beyond the limit of a thermometer reading to 360° C., only 3^{ccm} of gas were collected. On withdrawing the thermometer and raising the temperature to dull redness, 7^{ccm} more gas collected during a half-hour's heating, when the hard glass tube fused and blew out. Nothing but a drop or two of water condensed in the freezing mixture. Thinking that the gas which had collected might be air a taper was applied, when a slight explosion ensued, showing that a part only of the 10^{ccm} of gas was combustible.

Assuming the combustible gas to have been entirely methane, 10^{ccm} would weigh 0·007 gram. In reality the amount of combustible gas could not have been half this figure, since it exploded on the application of a taper. Since extraction of the heated limestone with boiling carbon disulphide left no weighable amount of material, it is safe to say that the matrix does not contain more than 0·02 or 0·03 per cent of carbonaceous matter of a pyrobituminous nature.

On examining the limestone left in the tube it seemed to be somewhat lighter in color. On being sprinkled on red litmus paper moistened with water, the color changed to blue, showing that the temperature had been sufficiently high to "burn" some of the limestone in an atmosphere of carbon dioxide and make it caustic. On being treated with acids it no longer

liberated the fetid odor previously mentioned, but left behind small amounts of a very voluminous insoluble black residue, largely carbonaceous, which from 1 gram of the ignited material did not exceed 0·0006 gram. Since the analysis of many "stinking" limestones, barites, cherts and quartz failed to show the presence of carbonaceous matter, it seems safe to say that the limestone composing the matrix by which the egg was surrounded does not contain as much as 0·1 per cent of carbonaceous matter. Furthermore, this small amount is of a pyrobituminous rather than a bituminous nature, requiring a temperature of approximately 800° C. to decompose it into gaseous decomposition products.

Evidence as to Origin.

In seeking for an adequate source of the tar present within the egg the most satisfactory answer may be obtained by the method of exclusion. The specimen was found in a region from which very few deposits of bituminous substances have been reported. It is necessary to assume that the colemanite came in from outside in solution, percolating through the matrix. The detection of boric acid in the limestone is, therefore, what would naturally be expected. If the very insoluble tar had come in through the matrix in a similar manner, it would be highly reasonable to expect to detect its presence, also, in the matrix. No tar was found except in the layer immediately in contact with the shell, where all evidence goes to show that the movement has been in the contrary direction, i. e., from within toward the exterior. In short, no evidence has been discovered to indicate that the tar came in from without.

On the other hand, there is considerable evidence to indicate that the tar could hardly have come in from an outside source. The tar is entirely too viscous to have come in its present condition through the solid matrix surrounding the egg. It is possible that it might have passed through the matrix dissolved in a lighter solvent which has since disappeared. In this case, after entering the egg, as the solvent evaporated the solution must have concentrated and tended to collect in one deposit on the bottom of the cavity. But there are several deposits of the material within the eggshell, some being diametrically opposite the main body of material which is assumed to have collected on the floor of the cavity. Similarly, the distribution of the tar inside the shell, coupled with its ready decomposability when heated, forbids the possibility of its having entered from without in the gaseous state. Considering the properties of the tarry material, there seems to be no reasonable possibility that it could have come in from an

external source, and have been deposited as it now is inside the eggshell.

Evidence of an adequate source for the tar in the limestone in which the fossil was embedded seems to be entirely wanting. There is no bituminous matter in the matrix, neither is there an appreciable quantity of any pyrobituminous material. Moreover, the ready decomposability of the tar with the formation of a product insoluble in petroleum ether indicates clearly that the temperature of its surroundings could never have been as high as 150° C. But at this temperature there was no evidence at all of pyrobituminous material, since the small amount of gas produced was liberated only at a red heat.

Considering the indubitable evidence that the tar was present before the colemanite came in, the small amount of bituminous matter present inside the shell, rather than an egg filled full of the material, is not without its significance.

Considering the highly fragile nature of an egg and the perfect state of its preservation, the conclusion that it was encased very soon after it was laid seems inevitable. This must mean the inclusion of its natural contents.

There is no reason to suppose that the egg of any previously existent bird, the shell of which is so similar to present day specimens as to be indistinguishable even under the microscope, would differ materially in the chemical nature of its contents.

In the eggs of the various families of birds which have been analyzed, there is but a slight variation in the relative proportions of the constituents, a difference not sufficient to invalidate the present considerations. The average composition of the edible portion of ducks' or geese's eggs may be taken as 15·5 per cent protein and 14·5 per cent fat. Very probably these figures closely represent the composition of water birds' eggs as a whole. The cubical contents of the fossil egg is 49^{ccm}. Assuming the specific gravity of its natural contents to have been 1 (it is usually a trifle greater), there would be about 7·5 grams of fat and somewhat more of dry protein. Assuming that the protein would lose all of its nitrogen and sulphur as ammonia and hydrogen sulphide or their equivalents, and that part of its carbon would disappear as the monoxide or dioxide or their equivalents, 40 per cent of the dry weight of protein would still remain if these decompositions took place without the intervention of oxygen from without. Under the same circumstances more than 90 per cent of the fat would still remain. There is, of course, the probability of a decomposition resulting in the formation of methane, but of the magnitude of this reaction no inferences can be drawn or allowances made. The assumption of

5 or 6 grams of residue from the contents of an egg of the size of the present specimen is not, therefore, unduly large.

It is difficult to estimate closely the amount of tar present in the fossil because of its varying distribution. The total quantity of bituminous matter could not have been more than 3 grams and was probably much nearer 2 grams. This amount might well have been derived from the fat alone. The absence of nitrogen in the bitumen may possible be accounted for by the suggestion that the easily decomposable protein may have entirely disappeared, while the more stable fatty constituents may alone have become bituminized.

The derivation of the tar from the original contents of the egg is, then, entirely possible, and from what is known of the process of bituminization its origin from such a source, under the conditions to which it has doubtless been subjected, is not in the least improbable. In the absence of any evidence to the contrary, therefore, since extraneous sources have been shown to be highly improbable, no reasonable ground seems to exist for doubting that the tar now present in the fossil has been derived from the natural contents of the egg.

Bearing.

After more than seventy years of painstaking investigation from the purely scientific as well as technical sides, the matter of the origin of bitumens is still an open question in many respects. Three entirely distinct theories have been before the world for years, ascribing their origin to three separate and distinct sources. The laboratory investigations of Moissan, especially for the theory of inorganic origin, and of Warren, Daubrée, Engler, Day and Sadtler for the organic side, have made it apparent that the results of experimentation support any theory and that artificial production indicates only the possibilities and not necessarily the realities as to the origin of bitumens.

Furthermore, every case of artificial production of bituminous matter has required a temperature much beyond the ordinary, a condition which an examination of natural deposits seems to render exceedingly improbable. "What geologists would be glad to find in Nature," says Professor Orton,* "as matching to and harmonizing with the facts with which they are obliged to reckon, would be a process in which the products of the organic world are transformed into mineral oil at ordinary temperatures with complete consumption of the substances acted upon so that no carbon residue would be left behind. They would also expect the transformation to be accomplished while

*Bull. Geol. Soc. Am., 9-90 (1898).

the organic matter still retained essentially its original character."

The attempt has been made repeatedly to realize these condition,—to ascertain whether unquestioned evidence could not be obtained to show from what kind of matter natural deposits have actually been derived. Many natural deposits have been carefully examined, but in no case can the evidence be considered as conclusive.

Thus, Wall pronounced the celebrated "pitch lake" of Trinidad to be of vegetable origin because of the remains of vegetation in all stages of transition which are present in the pitch. Jones found in the same pitch unquestionable animal remains; hence an animal origin is not improbable. Later Richardson* examined the "lake" and concluded that the conditions present offer "a far more reasonable basis for the assumption of a volcanic origin."

Fraas observed petroleum oozing from a coral reef in the Red Sea and concluded that the coral polyps are to-day being changed into bitumen. Binney noticed the same phenomenon about a peat bog in England and inferred that peat was being transformed at the present time into petroleum. Both of these are isolated instances. No other known coral reefs or peat bogs show evidence of similar changes, although conditions seem to be identical. Neither occurrence was thoroughly studied to ascertain what evidence there might be for or against the possibility of another origin. Neither instance is to be regarded, therefore, as unquestionable.

The occurrence of bitumen in fossils has hitherto been of no value as a means of furnishing direct evidence as to its origin, inasmuch as investigation proves that the bitumen need not, and often could not, have been derived from the organism with the remains of which it is to-day associated.

The discovery of the present specimen, a fossil egg partly filled with bituminous material, is under these circumstances of scientific value. For while absolute proof cannot be given, the evidence amounts almost to a demonstration that the bituminous substance now present in the egg represents a part of its original organic contents. In the absence of any evidence to the contrary we may accept that origin toward which all the evidence points. This specimen presents, then, one of the very few instances, possibly the only one, in which conclusive evidence is at hand to connect bituminous matter with the original material from which it has been derived by a natural process without abnormal conditions.

The absence of nitrogen from a bitumen material can not be regarded, therefore, as unquestioned evidence of its vegetable

*Jour. Am. Chem. Soc., 7–51 (1893).

origin, neither should the association of bitumen with boric acid be considered as a strong indication of volcanic origin for the bitumen.

University of California, Berkeley, California.

EXPLANATION OF PLATE XVIII.

FIGURE 1.—Side view of egg.
FIGURE 2.—Egg in the original matrix.
FIGURE 3.—Matrix from inner side, showing pits.
FIGURE 4.—In the matrix, end view.
(All figures natural size.)

Measurements.

Length of egg	62mm
Width " "	40
Circumference (longitudinally)	169
" (transversely)	124
Long diameter of enclosing capsule	120
Average thickness of enclosing capsule	12
Thickness of eggshell	·33

EXPLANATION OF PLATE XIX.

FIGURE 1.—Fractured surface of the broken egg, showing the contents; *t*, *t'*, and other darkened areas represent the bituminous material; the remainder of the cavity is filled with colemanite. (Natural size.)

FIGURE 2*a*.—A portion of the eggshell ground down on one side. *s*, corrugated outer surface; *c*, cellular lower layer. (×275.)

FIGURE 2*b*.—Cross-section of the shell fragment shown in figure 2*a*. *s*, corrugated outer surface; *c*, cellular lower layer. (×275.)

FIGURE 3.—Outer surface of the shell, showing corrugations of the surface and a large pit filled with bituminous material. (×275.)

FIGURE 4.—Cross-section of the pit shown in figure 3. (×275.)

Art. XL.—*On the Radio-activity of Natural Waters;* by Bertram B. Boltwood.

The occurrence, in the water of the public supply of Cambridge and the water from a number of other English localities, of a radio-active gas having properties similar to those of the radium emanation, has been demonstrated by J. J. Thomson* and confirmed by E. P. Adams.† Bumstead and Wheeler‡ have also shown that a similar radio-active gas is contained in the city water supply of New Haven, Conn., and in water from a spring at New Milford, Conn. That the waters from the hot springs at Bath and Buxton in England also contain radio-active gases has been demonstrated by Allen and Blythswood,§ who examined the gases given off at the springs and also the gases which escape from the water on boiling. The presence of minute quantities of radium salts in these waters and also in the sedimentary deposits formed at the point of issue, which has been observed by Strutt,‖ is of considerable importance since it has been shown by Rayleigh¶ that the gases which rise with the springs consist in part of helium.

Mention is made by Himstedt** of the occurrence of radium emanation in the waters of the thermal springs at Baden-Baden, Germany, and an examination by Elster and Geitel†† of the sedimentary deposits formed at these springs, has made it evident that these deposits contain radium compounds.

Curie and Laborde‡‡ have recently tested the gases given off at certain mineral springs of European origin and by the waters of these springs on boiling. They examined gases from nineteen different sources, fourteen of which they found to be radio-active. The radio-active properties of the gases corresponded to those of the radium emanation.§§

Radium emanation has also been found to occur in crude petroleum and natural gas, as well as in the air drawn from the ground in a number of different localities.

The object of this paper is to describe a method for the quantitative determination of the radio-active gas contained in a water and to furnish a convenient standard for measurement and comparison; also to offer some experimental evidence as to the origin of the radio-active properties of natural waters.

* Nature, lxvii, 609 (1903); Proc. Cambr. Phil. Soc., xii, 172 (1903).
† Phil. Mag., viii, 563 (1903).
‡ This Journal, xvi, 328 (1903); ibid., xvii, 97 (1904).
§ Nature, lviii, 343 (1903); ibid., lxix, 247 (1904).
‖ Proc. Royal Soc. London, lxxiii, 191 (1904).
¶ Proc. Royal Soc. London, lx, 56. ** Ann. d. Physik, xiii, 573 (1904).
†† Physikal. Ztschr., v, 321 (1904).
‡‡ Compt. Rend., cxxxviii, 1150 (1904).
§§ H. Mache, Physik. Ztschr., v, 441 (1904).

Method of Determination.

The gases dissolved in a water can be conveniently separated and collected by the method described by Reichhardt.* The apparatus as ordinarily constructed is too small for the purpose under consideration and requires certain modifications. It consists (fig. 1) of a vessel *A* made from sheet copper and having a capacity of about 9 liters. The orifice of this vessel, 9^{cm} in diameter, is surrounded by a heavy brass ring, 15^{cm} in outside diameter, to which can be attached by clamps a heavy brass

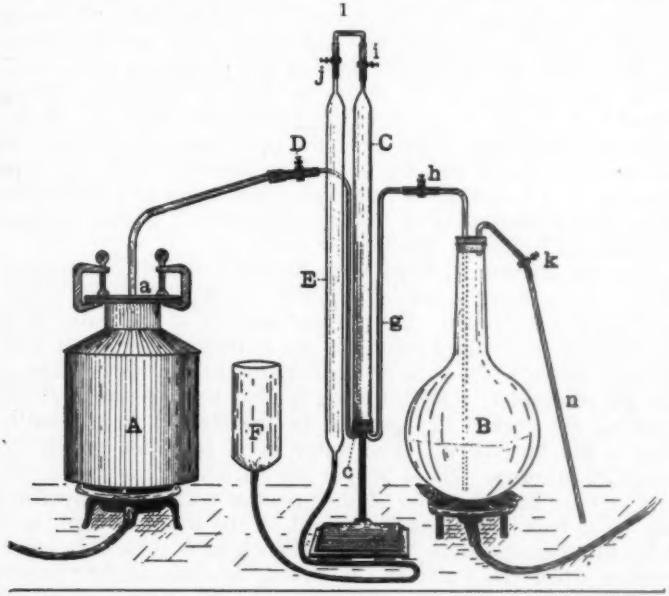


plate *a*, having a block-tin pipe soldered into an opening in its center. A rubber gasket, 3^{mm} thick, between the plate and the ring makes the joint perfectly tight when the clamps (6 in number) are screwed up tightly. A piece of thick-walled rubber tubing carrying a screw-pinchcock *D* connects the tin pipe with the glass tube *c*, which extends to the gas receiver *C*. This latter is 52^{cm} in length and 3^{cm} in diameter and has a total capacity of about 350^{cc}. The tube *c* protrudes about 20^{cm} into *C* beyond the rubber stopper at the bottom. The top of *C* is drawn out into a short, narrow tube and is closed by a rubber tube and a screw-pinchcock, *i*. The tube *g* passes from the bottom of *C* and is joined at *h*, by a piece of rubber tubing carrying a screw-pinchcock, to a glass tube which passes through a rubber stopper and extends to the bottom of the

* Hempel's "Gas Analysis" (translated by L. M. Dennis).

flask *B*. This flask has a capacity of about four liters. Through the stopper which closes it, there also passes a short glass tube attached by a short rubber tube to the glass tube *n*. The end of *n* dips into a good-sized beaker. The contents of *A* and *B* can be brought to boiling by the heat from two large gas-burners placed below the vessels.

In making a separation of gas, the flask *B* is first filled about one-half full of distilled water, which is boiled vigorously for about fifteen minutes. In the mean time the vessel *A* is completely filled with the water to be tested, the cover *a* placed in position and secured by the clamps, the rubber tube *D* disconnected from the tin pipe, and the pinchcocks are all opened. At the end of the 15 minute interval the pinchcock *k* is closed, when the pressure of the steam in *B* will force the boiling water from *B* into *C* and the tubing connected with it. When these are completely filled with the hot water, the pinchcocks *D* and *i* are closed and the cock *k* is opened. The tin pipe attached to *a* is now filled full of distilled water and the rubber tube *D* is slipped over it. The pinchcock *D* is then opened and the gas lighted in the burner under *A*.

The gas burette *E*, filled with distilled water, is connected with *i* by a short piece of capillary tubing, and the screw-pinchcock *j* is opened. As the temperature of the water in *A* approaches the boiling-point, the gas is freely disengaged and, passing through the tube *c*, accumulates in the upper part of the gas receiver *C*. By lowering the balance-receptacle *F* and opening the cock *i* the gas can be transferred from time to time to the burette *E*. The water in *A* is boiled gently for about 20 minutes. By a proper regulation of the pinchcock at *k* and the burner under *A* the pressure within the apparatus can be so regulated that the height of the water column in *C* is about 10 centimeters. The pinchcock at *h* is used in emergencies when the water in *A*, having become slightly superheated, tends to boil too vigorously and the excess of steam threatens to force the accumulated gas out of *C* into *B*. In such cases the cock *h* is closed, the gas under *A* turned off and the cock *i* opened, permitting the excess of vapor to pass over into *E*.

Since natural waters almost always contain an excess of carbon dioxide gas, a few cubic centimeters of a strong solution of sodium hydroxide is added on introducing the sample into *A*. This combines with the free carbon dioxide and reduces the volume of gas set free on boiling.

After all the gas obtained from a given sample of water has been transferred to the burette *E*, it is introduced into an air-tight electroscope. This operation is carried out in the following manner:

The air in the electroscope is exhausted until the pressure is about one-half atmosphere. To one of the stopcocks of the electroscope a small T-tube is attached by a short length of rubber tubing. The branch of the T-tube connected with the rubber tube contains a filling of granulated, anhydrous calcium chloride held between plugs of cotton wool. The rubber tube *j* of the gas burette is slipped over another branch of the T-tube, and the third branch is closed by a short rubber tube plugged with a glass rod. The pinchcock *j* is first opened and then the stopcock of the electroscope is opened, so that the gas is drawn very slowly into the electroscope. When the water in the burette has risen to the junction of the side tube, the pinchcock *j* is closed and the plug removed from the side tube, permitting the external air to pass into the electroscope and sweep with it any of the gases from *E* remaining in the tube and connections. When the atmospheric pressure is established in the electroscope the stopcock is closed and the apparatus disconnected.

In the tests which will be described later in this paper the average volume of gas obtained was about 150^{cc}. The capacity of the electroscope used was about 530^{cc}, so that under the conditions which have been described about 100^{cc} of atmospheric air swept through the connecting tubes before the normal pressure was established in the interior of the electroscope.

The activity of the gas from the water was measured in the electroscope, which has been described in a previous paper.* The gold leaf was charged by a battery consisting of 216 small, lead storage cells, at a potential, therefore, of about 432 volts. The positive terminal of the battery was earthed and connected with the case of the instrument; the negative terminal was connected with the top of the rod supporting the gold-leaf. The normal air-leak of the instrument was low and quite constant, and was equal to approximately 0·012 division per minute. The readings obtained with each measurement of gas were corrected by this quantity.

Because of the initial rise in the activity when the emanation is first introduced into the electroscope, due to the formation of "emanation X" on the walls of the vessel, the rate of leak at the end of three hours was taken as the measure of the activity.

Standard.

One of the most important points in the measurement of the radio-activity of the gas contained in a water is that the results shall be given in the terms of some standard which will permit the direct comparison of the results obtained by different experimenters. In the investigations conducted by

* This Journal, xviii, 97 (1904).

Curie and Laborde the standard adopted is the quantity of emanation produced by one milligram of pure radium bromide in one second. Such a standard would suffice for all immediate needs if it were not for the fact that it is impossible for others to obtain at present even small quantities of radium bromide of known and established purity. Other investigators have adopted the plan of expressing the activity in terms of the number of ions produced per second in a volume of one cubic centimeter. This is difficult to determine with accuracy and its indirect calculation is uncertain.

The standard here suggested and employed is the quantity of radium emanation set free when a known weight of uranium in the form of a natural mineral is dissolved in a suitable reagent.* The mineral which has been used is a pure uraninite from North Carolina. It was dissolved in aqua-regia, the solution diluted with water and the gas removed by boiling. The details of the operation follow:

The sample of uraninite was finely pulverized in an agate mortar. A portion on analysis was found to contain 82·46 per cent of uranium. A quantity of the pulverized mineral equal to 0·0121 was weighed out into a small tube made by cutting off about 4^{cm} of the bottom of an ordinary glass test-tube. The tube was lowered by means of a short piece of common thread into a flask of about 100^{cc} capacity, which had been previously filled about one-half full of distilled water. A rubber stopper with which the flask could be closed carried a glass tube, which could be pushed through the stopper until the lower end was just above the surface of the water in the flask. Beyond the stopper the tube was bent at a right angle. The stopper was placed very loosely in the neck of the flask, the tube which it carried being at the same time inserted in the top of the tube containing the mineral. On releasing the end of the thread at the right moment this dropped into the flask, leaving the tube floating on the water and supported in an upright position by the fixed tube within it. The rubber stopper was then tightly inserted in the neck of the flask and about one cubic centimeter of aqua-regia was introduced into the tube containing the mineral, a small pipette with a long, thin, capillary tube being used for this purpose.

The open end of the tube was then connected with the rubber tube *D* (fig. 1), the vessel *A* having been removed. The pinchcock *D* was opened, the flask and contents were warmed gently and the uraninite was dissolved. When the solution of the mineral was complete the tube extending into the flask was drawn out through the rubber stopper until the opening was just below the stopper. This permitted the tube containing

* This Journal. xviii, 97 (1904).

the solution of the mineral to fall on its side and fill with water. The contents of the flask were now boiled for about 20 minutes, a few snips of platinum foil having been placed in the flask to prevent bumping. The gases which accumulated in the tube *C* were transferred to the gas burette *E*, allowed to stand for 15 minutes and then introduced into the electroscope. The water in the flask *B*, the tube *C* and the gas burette *E* contained a little sodium hydroxide to absorb any chlorine which might be produced in the reaction. The time which transpired from the boiling off of the gas to its introduction into the electroscope (about 30 minutes) was sufficient to reduce the activity of the thorium and actinium emanations also present to a negligible value.

The rate of leak as determined at the end of three hours was taken as the basis of calculation, and was considered as equal to the activity of the radium emanation associated with 0·0100 gram of uranium. This leak was equal to 1·76 division per minute. A fall of the gold-leaf equal to 0·001 division per minute was therefore equivalent to $5{\cdot}68 \times 10^{-6}$ grams uranium.

Calculation of Initial Activity.

In most cases it is either impractical or altogether impossible to carry out the measurement of the activity of the water at the source of the spring. A certain length of time, either a few hours or several days, must elapse between the time of collection of the sample and the time that the test is conducted. Since it is highly probable that the activity of most, if not all, radio-active waters is due *chiefly* to dissolved radium emanation, this activity will become regularly less on standing. The decay of the radium emanation will follow the simple exponential law expressed by the equation:

$$I = I_0 e^{-at},$$

in which I represents the activity after the interval t, I_0 the initial activity, e the base of the Napierian system of logarithms and t the elapsed time expressed in hours. The value of the constant a is 0·00724 as determined by Curie, 0·00778 as determined by Rutherford and Soddy, and 0·00744 as determined by Bumstead and Wheeler.*

The initial activity of the water can therefore be calculated from the observed value of I. A convenient form of the equation is then

$$I_0 = Ie^{at}.$$

Radium Salts in Solution.

The presence or absence of radium salts in solution can be demonstrated by boiling about 10 liters of the water, a little

* This Journal xvii, 97 (1904).

acetic acid being added to prevent the precipitation of carbonates. After boiling, the water is allowed to stand for several hours in contact with the air and is then introduced into a bottle and tightly sealed. The capacity of the bottle should be such that the water completely fills it, leaving only the smallest possible air space below the stopper. The water is then allowed to stand for a sufficient length of time (say 16 days) and is then boiled again in the apparatus shown in fig. 1. If radium salts are present in the water, the gases given off on this second boiling will contain the accumulated radium emanation, and the relative quantity of radium present can be calculated from the observed activity of the gas.

Radio-active Waters.

A considerable number of samples of radio-active waters have been examined by the method herein described. Data on only three of these is at present available. The sources of these three samples were the following:

No. 1. Water from a spring at Windham, Me. This spring is known as the "Maine Granite Spring," and is stated to issue from a granite and sandstone formation, to have an estimated flow of 100 gallons per minute and to have a temperature of 43° Fahr. throughout the year. This sample was tested four days from the time of collection and was obtained through the courtesy of Prof. Chas. F. Mabery.

No. 2. Water from a spring in one of the public parks of the city of New Haven, known as "Cold Spring." The formation immediately adjacent to the spring is red sandstone, and the temperature of this spring on September 5, 1904, was 52° Fahr. The flow is small.

No. 3. Water of the city supply in New Haven, drawn from the pipes in the laboratory.

The radio-activity of the gases from these samples is given in the table which follows:

TABLE.

Sample No.	Liters taken.	Leak measured.	Leak per liter.	I.	I_o.	
1	8·9	9·91	1·11	63·22	128·6	calculated.
2	8·9	0·61	0·068	....	3·9	measured.
3	8·9	0·0036	0·0004	....	0·025	"

The leak is expressed in divisions per minute, the values of I and I_o are expressed in terms of grams uranium $\times 10^{-4}$ per liter of water. The value given for No. 3 is the mean of three separate determinations. The value of the constant, a, employed in the calculation was that determined by Bumstead and Wheeler.

Samples Nos. 1 and 2 were tested for radium salts in solution with negative results. It has been shown by Bumstead and Wheeler that no radium salts are present in the New Haven water (No. 3).

The radio-active properties of the gases from the first two samples were carefully examined and were found to correspond with those of the radium emanation. The activity fell to one-half in approximately four days and the rate of decay of the excited activity agreed with that of the "emanation X" from radium.

Origin of the Radio-active Properties.

The following experiments were carried out with a view to determining the possible source of the radio-active properties in the waters.

A quantity of uranium minerals was pulverized in an iron mortar and passed through a 100-mesh sieve. The minerals consisted chiefly of uranophane, but contained also some gummite, autunite and a small quantity of uraninite. The greater quantity of the material represented the final decomposition-product of uraninite when subjected to the action of percolating waters. The material taken weighed 80 grams. It was placed in a flask and about 500^{cc} of distilled water were poured over it. The contents of the flask were mixed thoroughly and allowed to stand, with occasional shaking, for about twenty-four hours. Some of the mineral was in such a fine state of division that the water remained very turbid after standing undisturbed over night.

The mineral was filtered off on a Buchner filter and the filtrate was boiled (to expel emanation). The water was cooled, introduced into a two-liter bottle with glass stopper, diluted with distilled water until the bottle was quite full and the stopper tightly inserted. The water was allowed to stand for four days, and the gases which it contained were then boiled off and tested in the electroscope. The activity of the gas was equivalent to 0·016 division per minute.

After filtering off the water as described above, the powdered minerals were washed twice with distilled water and the excess of water removed by suction. 100^{cc} of cold distilled water were then poured over the mass on the filter and drawn through it, this filtrate being separately collected. The filtrate was allowed to stand in an open beaker for one-half hour and was then boiled, the gases given off being collected and introduced into the electroscope. The leak at the end of three hours was 0·240 division per minute.

The mineral powder on the filter was washed back into the

flask and about 500^{cc} of water added. The water was boiled for three hours. The mineral was then filtered off and the filtrate boiled for one-half hour. The filtrate was diluted, sealed up for four days and then boiled again. The gases given off were tested for radio-activity in the electroscope and the observed leak was 0·034 division per minute.

About 80 grams of the same mineral mixture but in coarser powder had been shut up in a flask for about eight days. A sample of the gas in the flask withdrawn and separately tested showed that the total accumulated emanation in the flask had an activity equivalent to approximately 1700 divisions per minute. The gas was drawn from the flask into a 4-liter bottle by allowing the water with which the bottle was filled to run out until only about two liters remained. The bottle was then closed and shaken vigorously for about five minutes, and was then allowed to stand undisturbed for about thirty minutes. Water was then run into the bottle until all of the gas was displaced, the gas being collected in a second bottle (see below). Care was taken to remove any small bubbles of gas adhering to the neck of the bottle, and the water it contained was then introduced into the boiling can. The gases were boiled out of the water and tested in the electroscope. The activity of the gas obtained was equivalent to 80 divisions per minute.

The second bottle mentioned above, having a capacity of four liters, was filled one-half full of the gas from the first bottle, the gas being introduced at the top, while the water with which it was at first filled was permitted to flow out through a tube reaching to the bottom. Care was taken to avoid any agitation of the water and the gas was allowed to stand in contact with it for about two hours. The bottle was then completely filled with water by means of a tube reaching to the bottom and the gas was displaced. The activity of the gas obtained from the water on boiling was equivalent to a leak of 0·40 division per minute.

Summary.

From the results of these experiments it is apparent that by the action of cold, pure water on the uranium minerals used only a very slight trace of the radium contained in them is dissolved. The action of hot water is only slightly greater than that of cold water. Even brief contact with uranium minerals can impart to water very marked radio-active properties due to dissolved radium emanation. Water can also acquire very readily measurable quantities of radium emanation by simple contact with gaseous mixtures containing the emanation.

On applying these data to the occurrence of natural radio-active waters, it would seem as if all the observed facts could be readily explained. An extremely minute trace of uranium minerals in the rocks and soil through which the waters percolate in their underground passage would be sufficient to impart to them radio-active properties, which could be readily detected by the sensitive method at command. It can be anticipated that waters which rise through strata containing appreciable quantities of uranium minerals will be found more highly radio-active than any which have thus far been described. The results obtained from the examination of waters from springs in well-known uranium localities can be looked forward to with interest.

In those cases, at Bath and at Baden-Baden, where the waters have been found to carry traces of radium in solution, it can safely be assumed that the decomposing action of the waters due to their high temperature is still further increased by the pressure and by the fact that they contain various chemical substances in solution. These latter, while they promote the decomposition of minerals, may also retard the removal of the radium through the formation of insoluble sulphates, phosphates, etc. The fact that these waters on reaching the surface almost immediately deposit the greater portion of their radium is indicative of the difficulty with which that element is retained in solution.

In view of the extraordinary sensitiveness of the radio-active test for the radium emanation, it is very surprising that samples of gases from four of the springs examined by Curie and Laborde were found by them to be quite inactive.

139 Orange St., New Haven, Conn.,
October 11, 1904.

SCIENTIFIC INTELLIGENCE.

I. Chemistry and Physics.

1. *On the Action of Radium Emanations on Diamond.* — Having previously shown that diamonds, when exposed to the impact of radiant matter in a high vacuum, become blackened from a superficial coating of graphite, Sir William Crookes has recently experimented upon the action of the rays from radium upon these gems. Two diamonds having the same pale yellow color were selected, and one of them was kept for a fortnight close to a quartz tube containing 15 mg. of radium bromide sealed *in vacuo*. Comparison of the exposed diamond with the one not exposed showed no appreciable difference in color, and the same result was obtained after six weeks of exposure. The diamond phosphoresced brightly and continued to glow during the whole period of the experiment. The previously exposed diamond was now put inside a tube with radium bromide, the salt touching it on all sides, as it was thought possible that a screen of quartz might interfere with the passage of emanations which would act on the diamond. After a continuation of this exposure for seventy-eight days, the diamond had a darker appearance than the one reserved for comparison, and it showed a bluish green tint with no apparent yellow color. It thus appears that radium emanations, which darken glass in a marked manner, and quartz to a slighter extent, are also capable of darkening the diamond. The exposed diamond was now treated for ten days with mixtures of the strongest nitric acid and potassium chlorate, for the purpose of testing for a superficial formation of graphite. It was evident that graphite had been present, for the diamond lost its dull surface color and was as bright and transparent as the other stone, but its tint had changed from yellow to a pale blue-green.

The conclusion is reached that the radium emanations have a double action on the diamond. The β-rays (electrons) exert a superficial darkening, converting the surface into graphite in a manner similar to, but less strongly than, the more intense electrons in the cathode stream. But the alteration of the body color of the stone by emanations which are obstructed by the thinnest film of solid matter, even by a piece of thin paper, is not so easy to understand. It is believed that the alteration of color is a secondary effect, connected with the extremely phosphorescent state of the diamond during its exposure. It is not difficult to suppose that a chemical as well as a physical action may result. If the yellow color is due to iron in the ferric state, a reduction to the ferrous state would account for the change of color to a pale blue-green. This alteration of color may be of commercial importance in treating "off color" stones.

After the exposed diamond had been treated for ten days with the acid mixture, it was carried about with its unexposed com-

panion for about twenty-five days, and then both were laid together on a sensitive film for twenty-four hours. On development, the exposed diamond was found to have impressed a strong image on the film, but only a faint mark could be seen where the other stone had been. A repetition of the experiment confirmed the result.—*Chem. News.* xc, 1. H. L. W.

2. *Radio-active Lead, Radio-tellurium, and Polonium.* — Debierne has arrived at the conclusion that the radio-active lead of Hofmann and Strauss and the radio-tellurium of Marckwald are identical with M. and Mdme. Curie's polonium. The radiation of polonium is distinct from that of uranium, thorium, radium and actinium, and consists entirely of the almost non-penetrating α-rays, which are only slightly affected by a magnet. The radio-active substances which accompany bismuth, lead, and tellurium are all precipitated from acid solutions by hydrogen sulphide, and they have all been derived from pitchblende.

Having at his disposal a large amount of the residues from the extraction of radium, Debierne tried to obtain ratio-active lead. The lead nitrate obtained had a radio-activity only about twice that of uranium. Recrystallization of this nitrate was not effective in concentrating the radio-active substance, but when a large excess of hydrochloric acid was added to a concentrated solution of this nitrate, lead chloride crystallized out, leaving nearly all the radio-activity in solution. By repeating this operation several times the non-active lead chloride was eliminated, and the greater part of the activity was concentrated in a small quantity of matter. This portion, consisting chiefly of lead, was purified from small traces of copper and iron, and then transformed into nitrate. Upon adding the concentrated, slightly acid, solution of this nitrate to a large quantity of water, a very slight precipitate of basic bismuth nitrate was formed, which contained nearly all the radio-activity, and corresponded to very active poloniferous bismuth. The active matter thus obtained also showed all the properties of radio-tellurium; its solution gave an active precipitate with stannous chloride, and an extremely radio-active coating upon a thin piece of metallic bismuth.

It is thus seen that the same radio-active substance shows successively properties characteristic of radio-active lead, polonium, and radio-tellurium. The conclusion to be drawn is that there is no distinction between these three bodies, and it is evident from these experiments that a radio-active substance cannot be identified by chemical reactions, since analytical separations merely cause it to be shared among the different fractions. The only certain test is the nature of the radio-activity, and the identity of the radiations given by polonium, radio-active lead and tellurium would in itself predict the results that have been reached.

Circumstances were such that the lead nitrate used in these investigations was kept for three years before the work was completed. During this time it retained all of its feeble activity, although samples of polonium prepared from it gradually lost

this property. The author believes that the constancy of the activity must depend upon external conditions which it will be very important to determine, and he suggests the possibility that under certain conditions the activity of other substances, such as uranium, thorium, radium, and actinium, will diminish and disappear in the same manner as that of polonium.—*Comptes Rendus*, CXXXIX, 283. H. L. W.

3. *Condensation of Helium and Hydrogen by Charcoal.*—As a continuation of his studies on the condensation of gases by charcoal,* SIR JAMES DEWAR has obtained some interesting results with hydrogen and helium. Two discharge-tubes, provided with small condensers containing 1 or 2 g. of wood charcoal were filled, one with hydrogen and the other with helium at atmospheric pressure. The little charcoal condensers were now plunged into liquid hydrogen, with the result that the vacuum became so high that no electric discharge would pass in the tube filled with hydrogen, while in the tube containing helium the vacuum was high enough to obtain the phenomenon of phosphorescence under the action of the discharge. Two similar tubes containing helium from different sources were then subjected to the action of liquid hydrogen boiling under exhaustion, which produced a temperature of 15° absolute. In each case the vacuum resulting from the occlusion of the helium was so high that a coil giving a spark of 4^{cm} in air had to be used to obtain an intermittent phosphorescent discharge. From comparative experiments with hydrogen and helium it is concluded that the boiling point of helium is about 6° absolute.—*Comptes Rendus*, CXXXIX, 421. H. L. W.

4. *Die Riechstoffe;* von Dr. GEORG COHEN. 8vo, pp. 219. Braunschweig, 1904 (Vieweg und Sohn).—This book deals with those organic products—synthetical and natural—that are distinguished by some characteristic odor, particularly those which have found commercial application in the manufacture of perfumes. A great number of synthetical products are described, including alcohols, ethers, esters, aldehydes, ketones, and bases; and the reactions by which each class can be identified are discussed. A part of the book is devoted to tables relating to the numerous ethereal oils; their physical constants and chemical compositions are given, together with the names of the plants from which the oils are obtained. A short discussion of the relation between odor and chemical constitution is also given. The references to patent literature are very full. While the book will be of little interest to the theoretical chemist, it will be of use to the technical chemist who is interested in the manufacture of perfumes. T. B. J.

5. *Volumetric Analysis;* by FRANCIS SUTTON. Ninth edition, revised and enlarged. 8vo, pp. 617. Philadelphia, 1904 (P. Blakiston's Son & Co.).—This standard work on volumetric analysis is so universally known among English-speaking chemists

* See this volume, pp. 290 and 295.

that the appearance of this new edition requires no comment, except the statement that it contains some important changes and additions. H. L. W.

6. *Emanation of Radium.* — Sir WILLIAM RAMSAY from a careful study of this emanation concludes that it behaves like an ordinary gas resembling the gases of the argon family. It is luminous and obeys Boyle's law. A table of wave lengths of its spectrum is given. The gas is probably monatomic with a density of about 80 and an atomic weight of 160. Its electrons cannot be made to penetrate other bodies. The name *Exradio* is proposed for this gas.— *Comptes Rendus*, June 6, 1904, pp. 1388–1394. J. T.

7. *Emanations—Radiations.*—BERTHELOT suggests that surface films of volatile substances may account for many of the observed phenomena of radio-activity. In this connection the smell of metals is significant.— *Comptes Rendus*, June 20, 1904, pp. 1553–1555. J. T.

8. *Conduction of Electricity through high Vacua.*—Hon. R. J. STRUTT believes from his experiments that, even in high vacua, there is a loss of electricity from a charged body, in presence of the α-rays, independent of traces of residual gas. A rod of bismuth was made radio-active by a deposit of radio-tellurium which emitted α-rays only. The rod was attached to an electroscope. The exhaustion was pushed to the degree that no discharge could be forced through a Röntgen tube connected with the apparatus. The leak seemed to be distinct from that which is due to the ordinary ionization of gases. The author believes that the leak results from the particles torn off from the bismuth by the issuing α-ray. No details are given in regard to the character of suspension of the rod.—*Phil. Mag.*, Aug., 1904, pp. 157–158. J. T.

9. *Negative Ions from Heated Metals and Oxides.* — Many observers have studied the formation of positive or negative ions on heated metals. A. WEHNELT has shown that not only metals but a large number of metallic oxides possess the same property and to a much higher degree than the metals. He continues his investigation in this article and sums up his results as follows :

If platinum foil is covered with the oxides of the earth alkali (Ca, Ba and Sr) the cathode fall of potential is much lessened, from the numerous negative ions which are emitted. It was found at atmospheric pressure that negative ions issued even at a dark red heat from the oxides, while pure platinum held negative ions even at a very high temperature. In a vacuum the oxides and also pure platinum emitted negative ions, the number of which increased with the temperature. With the oxides the number of ions was 1000 times greater than with platinum. Calculation showed that the negative ions per volume-unit of the metallic oxide are 100 times greater than the number of the molecules in the same volume, so that one must assume that to each molecule of the oxide numerous negative ions are combined. The lessen-

ing of the cathode fall when glowing metallic oxides are used is due to emission of negative ions. By means of this property of emission very strong currents can be sent through a gas even at low pressures.—*Ann. der Physik*, No. 8, 1904, pp. 425–468.

J. T.

10. *Electro-chemical Equivalent of Silver.*—Determinations of this constant has been made by the following observers:

Mascart	0·011156
F. and W. Kohlrausch	0·011183
Lord Rayleigh and Mrs. Sidgwick	0·011179
Pellat and Potier	0·011192
Kahle	0·011183
Patterson and Guthe	0·011192
Pellat and Leduc	0·011195

The last determination with, it is claimed, more accurate determinations of the horizontal intensity of the earth's magnetism, the strength of the electrical current and the time, has been made by G. Van Dijk and J. Kunst, who have obtained the value

$$a = 0,\ 0111823 \pm 0{\cdot}0000004 \text{ (m.F.)}$$

From the agreement of observations, this result is claimed to be accurate to $\frac{1}{10,000}$.—*Ann. der Physik*, No. 8, 1904, pp. 569–577.

J. T.

11. *Electric Effect of Rotating a Dielectric in a Magnetic Field.*—According to Maxwell's Electromagnetic Theory, an electromotive force should be induced in a dielectric and its amount—according to Lamor and Lorentz—should be $(1-K^{-1})$ times that in a conductor, K being the permittivity of the dielectric. H. A. Wilson has shown the existence of this effect by rotating a hollow cylinder of ebonite in a magnetic field, parallel to the axis of the cylinder, with suitable conducting brushes, the results of the experiment were as follows:

(1) A radial electric displacement, is produced in the dielectric when it is rotated in a magnetic field parallel to the axis of revolution.

(2) The direction of the displacement is the same as is produced in a conductor.

(3) The displacement is proportional to the magnetic field and to the rate of revolution.

(4) The amount of the displacement agrees with that calculated on the assumption that the induced E.M.F. in the dielectric is equal to that in a conductor multiplied by $(1-K^{-1})$.—*Proc. Roy. Soc.*, June 22, 1904, pp. 490–492. J. T.

12. *A Radio-active Gas from Crude Petroleum.*—E. F. Burton shows that fresh crude petroleum contains a strongly radio-active gas similar in its rate of decay and in that of the induced radio-activity to the emanation from radium and to the emanations obtained by various experimenters from mercury and from certain waters fresh from the earth. This radio-active gas decays approximately according to an exponential law, falling to half

value in 3·125 days. It produces an induced radio-activity, whose rate of decay is such that it falls to a half value in about 35 minutes. There are indications of the existence in crude petroleum of slight traces of a radio-active substance more persistent than the radium emanation.—*Phil. Mag.*, October, 1904, pp. 498–508.

13. *Absorption of Water Vapor in the Infra-red Solar Spectrum.*—F. E. Fowle, Jr., in No. 1, vol. II, of the Quarterly issue of the Smithsonian Miscellaneous Collection, details the results of a bolographic study, made at the Smithsonian Astrophysical Observatory, of the absorption of water vapor in the infra-red region of the solar spectrum. It is shown that "the selective absorption of water vapor, within the range of densities observed, seems to depend only on the amount of the absorbent present and is well expressed by Bouguer's formula. In other words, the absorption produced by a given quantity of water in the form of vapor, is the same whether the path is great through a small density or vice versa. Considering successive bands, for example 0·81μ, $\rho\sigma\tau$, Φ, Ψ, Ω, it may be noted that the selective absorption of water vapor is not greatest like the general absorption at the shorter wave-lengths, but increases as the wave-lengths of the bands increase. It varies from 10 per cent in the more shallow bands near A, at 0·76μ, to nearly 100 per cent in the bottom of Ω at 1·80μ, when only on exceedingly dry days is much indication of energy detected. However, in the separate bands themselves, when the increase in absorption on reaching the bands from the shorter wave lengths side is quite sudden, the absorption then more slowly decreases like the general absorption with increasing wave lengths."

14. *On the Action of Wood on a Photographic Plate in the Dark.* — Continuing his work on the action of various substances upon a photographic plate, W. J. Russell shows that this property probably belongs to all wood, some kinds, however, being much more active than others. The sample of wood must remain in contact with, or at a little distance from, the sensitive plate for a time varying from 30 minutes to 18 hours; the temperature must not be above 55° C. The wood of conifers is very active and gives definite pictures. A section of a branch of Scotch fir gave an excellent picture showing the rings of both spring and autumn growth; the former were very active and produced dark rings in the picture, the latter were inactive. If, as has been suggested, hydrogen peroxide, present in the resin, is the cause of the action, it is necessary to assume that the resin in the dark (autumn) rings is under such conditions that it cannot escape.

Pine wood acted in the same way as the fir; also the spruces, but with them the action is less definite and sharply marked, and in some cases the dark rings were also active. With larch wood the picture is the reverse of that of the fir, the dark rings being active, the light rings inactive. Of other woods, oak, beech,

acacia, Spanish chestnut and sycamore were active, while the ash, elm, horse chestnut and plane wood were comparatively but slightly active. Exposure to bright sunlight for a short time (5 to 10 minutes) served to intensify to a high degree the action of the active parts; this is true of all wood. This increased action lingers for a considerable time; red glass, however, prevents this increase of activity.—*Proc. Roy. Soc.*, lxxiv, 131.

I. Geology and Mineralogy.

1. *U. S. Geological Survey.* — The following publications have recently been issued:

Latrobe Folio, Penn., No. 110; by M. R. Campbell. The Latrobe district is in the midst of the Pennsylvania coal area and its general geologic structure and economic importance have long been known. There is, however, little discussion of physiographic history in the Pennsylvania reports, and it is particularly in this regard that the recent work of Mr. Campbell adds to our knowledge of Western Pennsylvania.

The Schooley peneplain is recognized in the summit of Chestnut Ridge. The Harrisburg peneplain, cut in the Schooley plain when the land stood 1200 feet lower than at present, is recognized here as well as in the Monongahela and Susquehanna Valleys. The Harrisburg peneplain is Early Tertiary. A still lower level is described as the Worthington peneplain. The broad valley floor of the Conemaugh, which is such a conspicuous feature between Blairsville and Tunnelton, is found to correspond to similar features on the Monongahela, Youghioheny and Allegheny rivers, and to date from pre-Quaternary times. This feature is described as the Parker strath. The abandoned channels and oxbows of these rivers are believed to be the results of ice dams in early Glacial time, and not connected with the draining of Lake Monongahela as suggested by Dr. I. C. White. The streams of this district flowed directly toward the ice front and with the advent of spring the ice melted first at the head of the stream. There was thus opportunity for many ice dams, temporary, or even continuing through several seasons. This hypothesis accounts for many abandoned channels in Western Pennsylvania, which otherwise are inexplicable.

Zinc and Lead Deposits of Northern Arkansas: by George I. Adams, assisted by A. H. Purdue and E. F. Burchard; with a section on the Determination and Correlation of Formations, by E. O. Ulrich, 115 pp., 27 pls., 6 figs., Professional Paper No. 24. In addition to the economic study of the lead and zinc deposits of northern Arkansas, Mr. George I. Adams presents a sketch on the geologic and physiographic history of that region. A number of faults already noticed by the Arkansas geological survey are described and proof given that they are normal faults and not thrust faults, as considered by Branner. A description is given of the brecciated dolomite

of the Yellville formation. The brecciation is believed to be due to pressure induced at the time of the folding in the Ouachita Mountain Ranges. Movements which resulted in folding and thrust-faulting in the Ouachita Mountains and open folding in the Arkansas Valley region are represented in the southern portion of the Ozark district by brecciation of individual beds without disturbing their horizontal position.

A Geological Reconnaissance across the Bitterroot Range and Clearwater Mountains in Montana and Idaho; by Waldemar Lindgren. 116 pp. 15 pls. 8 figs. Professional Paper No. 27.—The Bitterroot Valley is one of the most striking typographic features in the western part of the United States. It is two to nine miles broad, runs almost exactly north and south, and is depressed 5,000 feet below the deeply incised Bitterroot Range to the west. The structure of this valley and of the adjoining mountains has been worked out by Mr. Lindgren, and shows some remarkable and unique facts. The depression owes its existence to the normal fault, but the essential feature of this dislocation is the fact that the fault plane corresponds with the schistosity and jointing, so that there is every gradation between the molecular and molar motions, indicating that both result from the same forces. In the sheared zone there is "intimate and inseparable relation between schistosity and faulting." The striated slipping planes of the granite-schists are closely massed, as many as twelve of them sometimes occurring in a thickness of one inch. This locality would seem to be an excellent one to test the divergent views regarding schistosity and jointing. Mr. Lindgren thinks that the observations of the Bitterroot Range confirm the opinions of Mr. G. F. Becker: that there is no essential difference between jointing cleavage and schistosity, that they may both be produced at the same time, and that molecular movement is not necessarily confined to the zone of flowage. The Bitterroot Range forms one of the largest glacial areas known in the Cordilleras. Excellent illustrations of U-shaped valleys, cirques, and various glacial deposits occur throughout the Range.

2. *Baraboo Iron-bearing District, Wisconsin;* by Samuel Weidman. Wis. Geol. and Nat. History Survey, Bull. No. 13, 171 pp., 23 pls., 3 figs. The Baraboo district, Wisconsin, shows an interesting geological series, consisting of pre-Cambrian igneous and pre-Cambrian sedimentary and of Paleozoic strata. The iron ore is hematite developed from original limonite, and it is an interesting fact that the ores showed no surface outcrop but were found by drilling through sandstone and drift. In order to get at the iron ore it was necessary to understand the geological structure of the pre-Cambrian quartzite (Baraboo). A detailed study of the quartzite shows that its structure consists of a double syncline, on the top of which is deposited unconformably Potsdam sandstone. The hypotheses of Irving, and later of Salisbury, are shown not to be in accordance with the facts.

3. *Chemical Survey of the Waters of Illinois;* by A. W. PALMER, 243 pp. 52 pls.—The factors which make for and against a satisfactory water supply of a state and the relation of geologic structure to these factors are emphasized by the recent report of the Illinois Water Survey. A study has been made of the sanitary condition of the waters of lakes, streams, and wells, as shown by 460 analysis. Particular attention has been devoted to the Illinois River during 1897–1902, and it has been found that the waters of that stream, where they enter the Mississippi, contain less organic matter than previous to the construction of the Chicago Sanitary Canal. A chapter on the Geology of Illinois as related to its water supply is written by Professor Rolfe.

4. *Submerged Tributary of the St. Lawrence.*—In the Transactions of the Royal Society of Canada, vol. ix, Section iv, pp. 143–147, H. S. POOLE publishes a chart and description of an ancient river system with headwaters in Pictou County, Nova Scotia, and receiving important tributaries from Prince Edward, Magdalen, and Cape Breton Islands. The river follows closely the ridges of hard rock near shore, and submerged mounds suggest a continuation seaward of the Carboniferous coast terrace. The presence of this river maintaining its characteristic features through several sub-cycles is sufficient to account for the absence east of Pictou and along Cape Breton of the softer members of the Carboniferous series, without assuming fault boundaries.

5. *Sands and Sediments;* by T. MELLARD READE and PHILIP HOLLAND (Proc. Liverpool Geol. Soc., 1903–04, pp. 3–20).—An investigation has been begun to find out whether there exists any relation between the size of the particles or grains of sand and their chemical constituents; also the degree of minuteness to which particles can be ultimately reduced by natural agencies, and how, and in what way this takes place. These investigations, when completed, will indicate in some degree how far purely mechanical sediments may be carried out and deposited in the ocean. An inquiry is also being made into the question of the origin of limestone by the deposition of infinitesimal particles carried out from the land. The investigations so far give "hints of the possibility of deep-sea limestone being formed in an inorganic way."

6. *Palæontologia Universalis.*—The writer desires to call the attention of American Geologists to the fact that this very important work has but 21 subscribers in the United States, while France has 63 and Germany 96. Certainly the geologists and geological libraries of this country are not yet supplied with this publication. Fasciculi I and II have been issued; these contain 97 sheets redescribing and refiguring 46 of the old and little known species. It is intended to issue annually from 150 to 160 sheets, treating of about 80 species. The annual subcription price is $8.00. Subcriptions may be sent to G. E. Stechert, No. 9 East 16th street, New York City. Those persons or institutions desiring further information regarding this work, with samples of the plates, will

be supplied on application to Professor Charles Schuchert, Yale University Musem, New Haven, Conn. CHARLES SCHUCHERT.

7. *Interferenz-Erscheinungen im polarisirten Licht; photographisch aufgenommen;* von Dr. HANS HAUSWALDT in Magdeburg. Neue Folge, 1904.—The series of eighty beautiful plates contained in this work forms a very valuable aid to the study of the behavior of crystal sections in polarized light, in fact so excellent are the photographic reproductions that, except for the absence of color, the student can learn almost everything from them that he could from the specimens themselves. This work follows the "Interferenz-erscheinungen an doppeltbrechenden Krystalle im convergenten polarisirten Licht" published two years since by the same author, while still further plates are promised in the future. The plan of the series now issued has been made by Professor Liebisch of Göttingen, to whom the work is dedicated; Dr. Siedentopf, of the optical works of Carl Zeiss in Jena, has also contributed materially to the success of the enterprise in various directions. The execution of the plates (by Studders and Kohl of Leipzig) leaves nothing to be desired.

A complete statement of all that is given in this series would require the reproduction in full of the table of contents. The opening plates exhibit the axial figures for several species (calcite, topaz, gypsum, albite) in converging polarized light as modified by the aperture of the condenser (C_1 and C_2 with num. ap.$=0{\cdot}636$ and $1{\cdot}168$ in each case). Then follow a number of plates showing the limiting curves of the complete interference figures in converging light for calcite and quartz under varying conditions.

The influence of the color of the light source is shown for calcite, quartz, cerussite and titanite, wave-lengths of 620–720$\mu\mu$ and 410–450$\mu\mu$ respectively being used in each case. Other plates show the dispersion of the optic axes of brookite for different colors; the effect produced by the combinations of mica plates of Reusch and of Noerrenberg; the interference bands of wedges of birefringent crystals in parallel polarized light; the spectral analysis of the interference colors of sections of birefringent crystals; the anomalous optical characters of beryl and the peculiar phenomena yielded by boracite, leucite, perofskite, also garnet, milarite and other species. Twin structure is exhibited for numerous species; also spherolitic structure; further, the birefringent phenomena called out in glass by rapid cooling and by pressure, and the effect of change of temperature and pressure in the case of crystals of various species. Finally, absorption phenomena are fully illustrated.

This summary will serve to show the great variety of phenomena exhibited by the upwards of three hundred figures of this unique work.

8. *Tableau systematique des Minéraux classés d'après leurs propriétés chimiques et cristallographiques;* par P. GROTH. *Traduit de la quatrième édition allemande* par MM. E. JOUKOWSKY et F. A. PEARCE. Avec corrections et additions de l'auteur. Préface

par Louis Duparc. Pp. viii, 188. Geneva, 1904 (Grebel, Wendler & Cie., Éditeurs).—French students are to be congratulated in having placed before them this translation of Professor Groth's admirable work, a work which occupies a unique place in mineralogical literature and which has exerted a great influence upon the progress of the science since the publication of the first edition thirty years since.

9. *An Introduction to the Study of Meteorites, with a list of the Meteorites represented in the Collection of the British Museum of Natural History on January 1, 1904;* by L. FLETCHER. Pp. 109, London, 1904.—The last edition of this guide to the meteorite collection of the British Museum, with its interesting introduction, was issued in 1896. Since that time the collection has increased notably, the total number of specimens recorded at the beginning of the present year being 557.

10. *Manual of the Chemical Analysis of Rocks;* by H. S. WASHINGTON. Pp. 183, 8vo. New York, 1904 (John Wiley & Sons).—The author states that the object of this book is to present to chemists, mining engineers, petrologists and others who have not made a particular study of quantitative analysis, a selection of methods for the chemical analysis of silicate rocks and especially those of igneous origin. There are probably few branches of science in which a greater amount of earnest, well intentioned work has been done in the last twenty-five years, with so much that is inaccurate and of little value in results, as in petrography in the making of rock analyses. They have, in large part, been made by beginners or by those having little skill, experience or knowledge of correct methods, with a corresponding loss of time and effort. A particularly bad feature of the case is, that it is not always evident or possible, contrary to what generally obtains in pure mineral analysis, to determine how inaccurate the results are. In these later years, however, a change has taken place in this respect and as high a standard of analytical excellence is now demanded in petrography as in any other branch of science.

Several causes have contributed to this result, especially the efforts of a number of earnest workers, among whom are to be chiefly mentioned the chemists of the United States Geological Survey as well as the author of this book.

On the other hand it may be said that there are not many things, when one considers the number of elements to be determined and the length of the processes involved, which demand greater skill and experience in analysis from the chemist than that of silicate rocks.

All this makes the appearance of this work a very timely one and it will be henceforth an almost indispensable adjunct to the library of every analytical chemist and petrographer. The author gives in full detail a description of the necessary apparatus, reagents, etc., and of the proper method of selecting material. The analytical processes selected are those which long

experience has shown to be the best, and the methods for carrying them out are so fully described, that with the attentive use of the work, even beginners may achieve good results, while the experienced analyst will find much that is of interest and value in saving time and work. It is well and clearly written and the field has been thoroughly covered. It is to be hoped that its appearance will do much to raise the standard in this field of scientific work. L. V. P.

11. *Notes on the Rocks of Nugsuaks Peninsula and its environs, Greenland;* by W. C. PHELAN. Smith Misc. Coll., Quar. Issue, vol. 45, pp. 183–212. 1904.—The author has made a study of a collection gathered by Professor Schuchert and Dr. David White. The collection embraced types of gneiss, diorite, syenite, peridotite, monzonite, granite and basalt, the latter containing native iron. Detailed petrographic descriptions of these are given and of several, complete chemical analyses were made. The paper adds considerably to our knowledge of the petrography of Greenland and will be read with interest by petrographers. L. V. P.

12. *Ueber den Kali-Syenit des Piz Giuf und Umgebung und seine Ganggefolgschaft;* von F. WEBER. Beitr. zur Geol. Karte der Schweiz Neu. Folge XIV Leif. Bern, 1904, 4°, 176 pp., pl. V.—The rock masses described in this paper lie in the western part of the Aar massive. The main mass of syenite forms a long slender lens in granitic rocks, about 13 kilometers long and bent slightly into an S shape. It is accompanied by dikes of more salic and femic characters. There are also varieties of the main syenite type. All these rocks, under the headings of syenite, aplite, granite porphyry, spessartite and kersantite, have been thoroughly studied and analyzed and the results are here presented, together with discussions of their relationships, origin, and the bearing of these on the general question of differentiation. It is an extended and careful piece of work which adds to our knowledge of local Swiss petrology and contains much of general interest to petrographers. L. V. P.

III. MISCELLANEOUS SCIENTIFIC INTELLIGENCE.

1. *Harvard College Observatory.*—Recent publications of the Harvard College Observatory include the following:

ANNALS, vol. xlvi, Part II, pp. 121–249, with plates I, II, Observations of Variable Stars made with the Meridian Photometer during the years 1892–1898; by Edward C. Pickering. Vol. liii, No. III, pp. 45–73 with plates I, II. The ninth Satellite of Saturn; by William H. Pickering. This paper gives a most interesting account of the search, begun in 1888, for the supposed ninth satellite of Saturn, and its identification in 1899 on photographs taken the year previous at Arequipa. Later observations have served to determine with accuracy the orbit of Phœbe, as the satellite has been called. It is found to have an eccentricity greater than that of any other planet or satellite and is exceeded

only by a few of the asteroids. The period is 546·5 days and its diameter is estimated at 200 miles. It is thus the largest body discovered in the solar system, exclusive of the comets, since the inner satellites of Uranus were found by Lassell in 1851; it is also by far the faintest object, its brightness being estimated as two magnitudes less than that of Hyperion, which is assumed to be of the 14th magnitude.

Vol. liii, No. IV, pp. 75–84 with four plates. A Study of Eratosthenes; by William H. Pickering. Some paragraphs from this paper are quoted below.

Vol. lvi, No. I, pp. 1–26 with two plates. Distribution of Stellar Spectra.

CIRCULARS: No. 83, Common's 60-inch Telescope; No. 84, Carnegie Grant of 1903; No. 85, The anonymous gift of 1902.

2. *A Study of a Lunar Crater.* — The following paragraphs, which form the concluding part of the "Study of Eratosthenes" by W. H. PICKERING, referred to above, will be read with interest in connection with the recent discussion of the features of the moon (see p. 314 of the October number). The author closes the detailed description of the crater and the changes in it observed by him as follows:

"Summarizing our knowledge so far, we find that there seem to be four canal systems, two large and two small. They are best seen in figure 11. In each there is a prominent lake from which three or more canals diverge in various directions. The largest of these lakes, which we will call I, is situated to the east of the central peaks. Three canals radiate from it. The second largest, which we will call II, is situated on the northwestern slopes of the central peaks. It also has three canals. III, at the extremity of ridge *A*, has four or five canals radiating from it, and a nearly concentric ring, similar to *Solis Lacus* on Mars. IV is a small and very faint lake at the extreme northern end of the floor, from which at least five minute canals radiate. It also is furnished with a somewhat ill-defined dark ring, composed in part of the lakes and canals of systems I and II. I reminds us somewhat of the *Syrtis Major* on Mars and the two large canals or branches which lead into it from the south, and form a rather characteristic Y at certain seasons.

These canal systems seem to be almost entirely independent of the surface configurations. Sometimes the central lake is on a mountain crest like III, and sometimes in the bottom of a valley like I. The canals sometimes, as in system II, descend one slope, cross a valley, and ascend another. They generally appear all at once throughout their whole length, but in at least two instances we have recognized a progressive motion. In one of these cases, *A*, the direction of motion was tangential to the lake III; in the other, *D*, it was radial and towards the lake I. In both cases the motion was down hill. *D* vanished on the ridge before it did on the lower slopes.

A few words may now be said on the chief objection that has been raised to the theory that these changes are due to vegeta-

tion, namely, the lack of water on the Moon. While it is true that water cannot exist in the free state under a pressure that is less than 4·6 millimeters, and while it is also true that no such pressure apparently exists upon the Moon's surface, still there is nothing to prevent water occurring beneath the surface of the ground, retained by the capillary action of the soil. It has been shown by Cameron (Science, 1903, xviii, 758) that water can be extracted by dry soil from a membrane against a calculated osmotic pressure of 36 atmospheres, or about 500 pounds per square inch. Since on the Earth plants can live on moisture which they have in turn extracted from such a soil, there seems no difficulty in understanding how they could live on the Moon, in a soil which could thus retain considerable moisture in spite of the low atmospheric pressure. Indeed if it were possible to conceive of an organism which could absorb its oxygen directly from vegetation, and store it during the lunar night, there is no reason why animal life should be impossible upon the Moon.

That the substance which we have called vegetation is frequently found in connection with deep clefts has already been pointed out by the author, in dealing with the crater Franklin, see "The Moon," page 56. That a dark patch of vegetation sometimes covers an area formerly occupied by ice has been shown in the case of Riccioli in the Harvard Annals, xxxii, 216. Finally, that different areas of vegetation in the same crater may appear and disappear at quite different times has been pointed out in the case of Alphonsus, in the Annals, xxxii, 33. It therefore appears that the various phenomena above described have all been indicated before in visual observations made at this Observatory. Their interest here lies chiefly in the fact that in Eratosthenes they are shown so clearly, and upon so large a scale, that we are now able to photograph them. We are thus able to share with other astronomers what in the case of visual observations can only be seen by those who have good enough atmospheric conditions to be able to detect them. In the case of visual observations other persons must place their faith on the judgment and accuracy of the observer, in the present case the photographs permit every reader to be his own observer and judge."

3. *Field Columbian Museum, Publication 95, Zoological Series*, vol. IV, parts I and II, pp. xx, 850, with sixty-eight plates and numerous text-figures.—These volumes are devoted to the "Land and Sea Mammals of Middle America and the West Indies," by Daniel Giraud Elliot. This admirable work follows the "Synopsis of the Mammals of North America and Adjacent Seas" by the same author and is intended to contain all the mammals of the remainder of the North American Continent, that is from the northern boundary of Mexico to the Province of Cauca, South America, including the coast islands, also part of Bahamas and West Indies. It is clearly presented and very fully illustrated.

4. *Statistical Methods with special reference to Biological Variation;* by C. B. Davenport. Second, revised edition, pp.

viii, 223. New York 1904 (John Wiley & Sons).—The first edition of this useful work was issued in 1899 (see this Journal, viii, 399). A second edition, somewhat enlarged, is now given to the public; the most important addition is that of the new statistical methods of Prof. Karl Pearson, his students and associates, with a summary of the results gained by them.

5. *Catalogus Mammalium, tam viventium quam fossilium;* a Doctore E.-L. TROUESSART. Quinquennale Supplementum, anno 1904. Berlin (R. Friedländer u. Sohn).—Fasciculus II, pp. 289–546, of the Supplement announced in the July number of this Journal (p. 94), has recently appeared. It is devoted to the Rodentia.

6. *Beitraege zur Chemischen Physiologie und Pathologie;* herausgegeben von FRANZ HOFMEISTER. Band V. Braunschweig, 1904 (Fr. Vieweg und Sohn).—The present volume of fifty pages is, like its predecessors, largely taken up with investigations on the proteids and their derivatives. A contribution by Dr. Kammann on the specific pollen toxin which gives rise to hay-fever, indicates that the poison belongs to the group of toxalbumins, is thermostable and not completely destroyed by proteolytic enzymes. These facts are of interest in connection with the recent attempts to induce immunity to hay-fever and to obtain a specific antitoxin. Various papers on blood-coagulation serve to render the explanation of this process more complex than ever before. Professor Röhmann has contributed an interesting paper on the skin glands (Bürzeldrüsen) of birds, throwing considerable light on the origin and composition of the secretion which they yield. The volume also contains several papers of physico-chemical interest, and a number of communications on enzymes, including important observations on amide-splitting ferments. L. B. M.

7. *Ostwald's Klassiker der exakten Wissenschaften.* Leipzig, 1904 (Wilhelm Engelmann).—The following parts of this series of scientific classics have recently appeared.

No. 143. Abhandlung über die Auflösung der numerischen Gleichungen (1835) von C. Sturm. Aus dem Französischen übersetzt und herausgegeben von Alfred Loewy. Pp. 66.

No. 144. Johannes Keplers Dioptrik, oder Schilderung der Folgen, die sich aus der unlängst gemachten Erfindung der Fernrohre für das Sehen und die sichtbaren Gegenstände ergeben (1611). Übersetzt und herausgegeben von Ferdinand Plehn. Pp. 114.

No. 145. Über die Konstitution und die Metamorphosen der chemischen Verbindungen und über die chemische Natur des Kohlenstoffs: untersuchungen über aromatische Verbindungen von August Kekulé. Herausgegeben von A. Ladenburg. Pp. 89 with a plate.